



# Coexistence between proposed Pacific DataVision LTE systems and existing Sensus FlexNet systems in the 900MHz band

Review and analysis by Real Wireless

# Version History

Version	Date	Comment	Who
5.0	26/06/2015	Issued to Sensus	RW

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# Summary of findings

1. Real Wireless has reviewed coexistence calculations and emission specifications proposed by pdvWireless (PDV) to protect adjacent FlexNet systems on behalf of Sensus
2. We have reproduced PDV's calculations using an independent model, **and agree broadly with PDV's calculation methodology**
3. We found that **the interference threshold proposed by PDV is inappropriate**, since it is based on inappropriate noise environment assumptions. Our review of field measurements conducted by Sensus suggests a threshold around **-170dBm/Hz** rather than the -160 dBm/Hz proposed by PDV
4. We have conducted a detailed review of the calculation parameters proposed by PDV and found that in many cases **the parameters are inappropriate**, resulting in a far greater level of interference than PDV has suggested
5. The table below summarises our findings regarding the extra attenuation needed for each: interference mode (uplink, downlink) case (challenging, moderate) and the interpretation of the proposed limits (A or B): Even in moderate cases **tens of dB extra attenuation is needed**
6. Additionally the **test conditions for specifying emission limits need to be properly specified** to account for the measured characteristics of real LTE devices: this could create a 7dB increase in emissions compared with the test conditions specified by PDV

Interference mode				Challenging Case		Moderate Case	
		Rule proposal	Interpretation	A	B	A	B
PDV UE aggressor to Sensus TGB victim (PU2FT)	UL	03-May	PSD dBm/Hz	-116	-114	-141	-139
			Extra attenuation needed (dB)	54	56	27	29
PDV eNodeB aggressor to Sensus endpoint victim (PB2FE)	DL	25-Mar	PSD dBm/Hz	-146		-155	
			Extra attenuation needed (dB)	24		14	
		03-May	PSD dBm/Hz	-128	-138	-138	-147
			Extra attenuation needed (dB)	42	32	31	22

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Note: blank cells were not calculated

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Annex 1: Out of band emissions from LTE UEs

Annex 2: Abbreviations



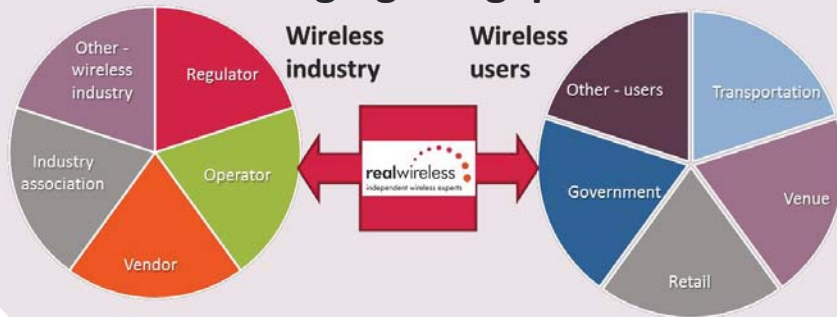
# 1. Introduction and scope

- pdvWireless (formerly Pacific DataVision, PDV) has made a proposal to FCC to realign the bandplan in the 900MHz spectrum adjacent to Sensus's FlexNet systems, introducing nationwide LTE systems into the band
- This proposal changes the basis for adjacent channel coexistence and raises the risk of additional harmful interference
- Sensus has commissioned Real Wireless to undertake a critical review and independent analysis of the PDV's proposals based on:
  - Documentation and technical model supplied by PDV
  - Information on FlexNet technology and deployments supplied by Sensus
- This slidepack represents the report from the Real Wireless analysis
- It is based on our best endeavours and assumes the accuracy and currency of the information supplied to us

## 2. About realwireless

- Leading independent wireless advisory firm, bridging the gap between the wireless industry and wireless users
- Team of over 35 experts with deep technology, business, market and economics experience
- Experience:
  - Technical and policy advice on 4G spectrum auction to Ofcom
  - Manage wireless at Wembley Stadium and other major venues
  - Founded and chaired Small Cell (Femto) Forum
  - Founded the UK Spectrum Policy Forum

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- Social and economic impact
- Regulatory support & advocacy

#### Markets

- Market evaluation
- Product roadmap definition
- Competitive analysis



## 3. About FlexNet systems

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## Overview of FlexNet

- The Sensus FlexNet system is a long-range radio network that serves as a dedicated and secure two-way communications highway for utilities.
- The network is designed to be highly reliable and resilient to suit the critical infrastructure needs of FlexNet customers
- FlexNet base stations, known as TGB, serve endpoints which are predominantly static (other modes of operation are also supported)
- In order to achieve high reliability, the FlexNet system operates in narrow channels from 1.6 kHz-30 kHz bandwidth width and 0.805-37.5 kbps adaptive modulation and coding schemes according to the endpoint needs and channel conditions
- Unlike mobile systems, FlexNet, as a critical machine-to-machine network requires highly reliable individual links to static locations and cannot rely on the statistics of mobility to overcome coverage deficiencies
- This is achieved via adaptive modulation and coding, automatic repeat requests and very sensitive base station receivers operating in low interference environments



## Scale of FlexNet deployments

- According to Sensus data, the scale of current US NBPCS FlexNet deployments is as follows:
  - 15.6 million endpoints
  - 692 customers
- New customers are added every month
- Several million additional endpoints to be deployed by existing customers (one customer alone has 2M to deploy)
- So while our analysis will focus on the impact of interference on individual base stations or endpoints, it should be recalled that any impacts could affect millions of customers and devices

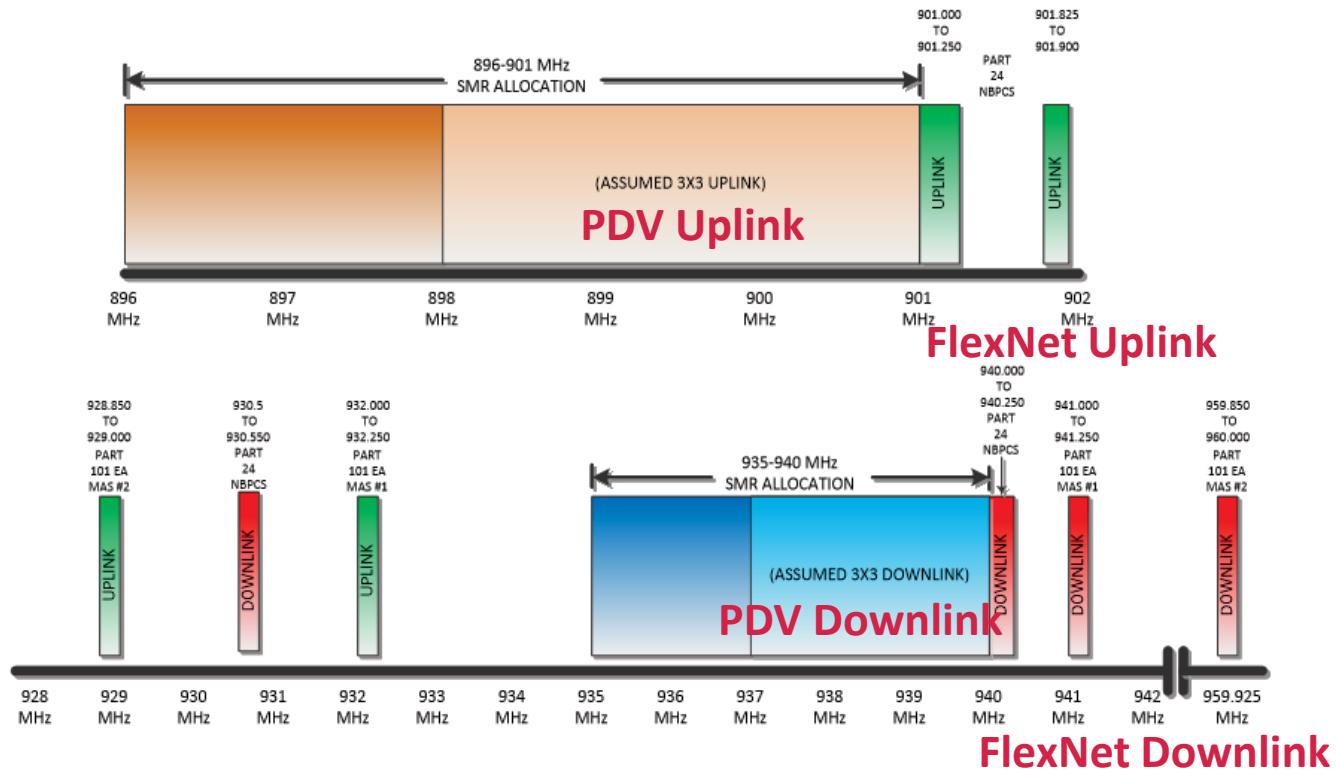


## 4. Overview of Pacific DataVision (PDV) proposals

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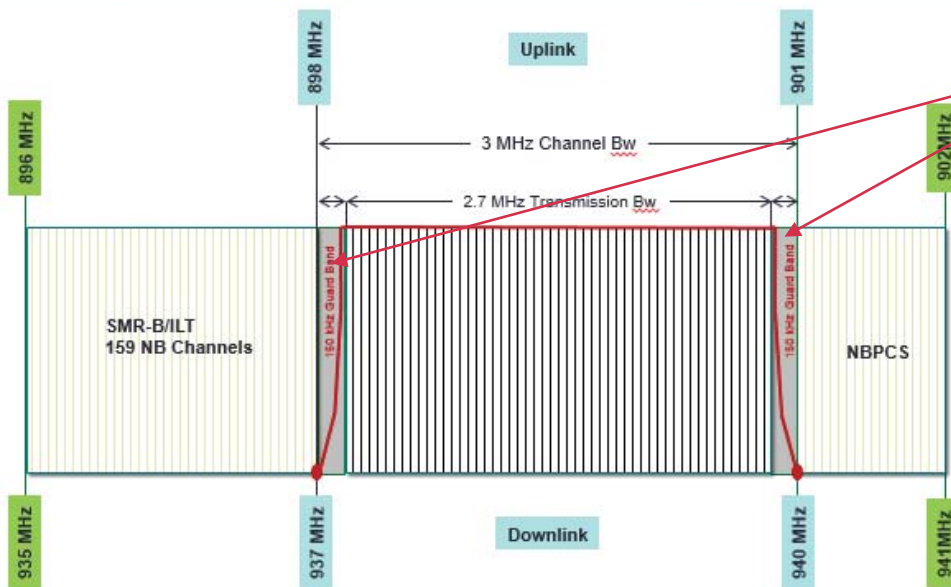
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# 900 MHz spectrum realignment proposed by PDV



# PDV's proposed channel usage

## PEBB Proposed LTE Band Plan & Channel Mask



The 2x150kHz guard band is an inherent feature of LTE, not a coexistence measure suggested by PEBB

- PDV proposes to allow UEs to transmit at up to 3W ERP

# PDV's proposed network deployment and usage

- Little information has been supplied by PDV relating to their planned network deployment and usage
- From their website [1]:

pdvWireless is building and supporting a state of the art, private push-to-talk network in major U.S. markets dedicated solely to dispatch centric businesses. This network will provide business customers with a true push-to-talk (PTT) user experience that has been missing in the marketplace for several years. This PTT network will minimize call set-up time, eliminate telephone tag and voicemail backlog. Utilization of this network will allow businesses to achieve operational efficiencies while reducing their costs of telecommunications.

## pdvWireless-DispatchPlus

DispatchPlus will be supporting a next generation PTT solution utilizing state of the art digital two-way radio technology integrated with proprietary cloud-based mobile resource management solutions. This DispatchPlus offering will combine the efficiencies of a digital network with the value of a cloud based work order management solution. This solution, including intelligent call prioritization, worker tracking, status mapping and other workforce management capabilities will provide business customers substantial benefits and cost savings including improved workforce productivity and increased operational efficiencies.

Businesses in the markets where pdvWireless will be providing service will be able to reduce their telecommunications expenditures while providing superior customer service to their clientele. In the long term, pdvWireless will provide added value to the small business marketplace by providing solutions focused on meeting all their wireless telecommunications needs in the most cost effective manner possible.

## pdvWireless-pdvConnect

pdvWireless is a recognized innovator in developing mobile workforce communications and management solutions. The company will continue to provide advanced voice & photo documentation along with GPS tracking and cloud-based management tools that increase profitability and workforce efficiency under the pdvConnect product offering. pdvConnect technology is utilized at a wide variety of enterprises in the United States and Mexico, ranging from national deployments at Fortune 500 companies to local deployments by other businesses and governmental agencies.

- Based on this and the other information supplied, we understand that PDV's network will be:
  - Nationwide
  - Based on LTE technology
  - Supporting a range of mobile and potentially static devices
  - Operating entirely in the proposed realigned 900 MHz spectrum block of 2 x 3MHz

[1] <http://www.pdvwireless.com/>

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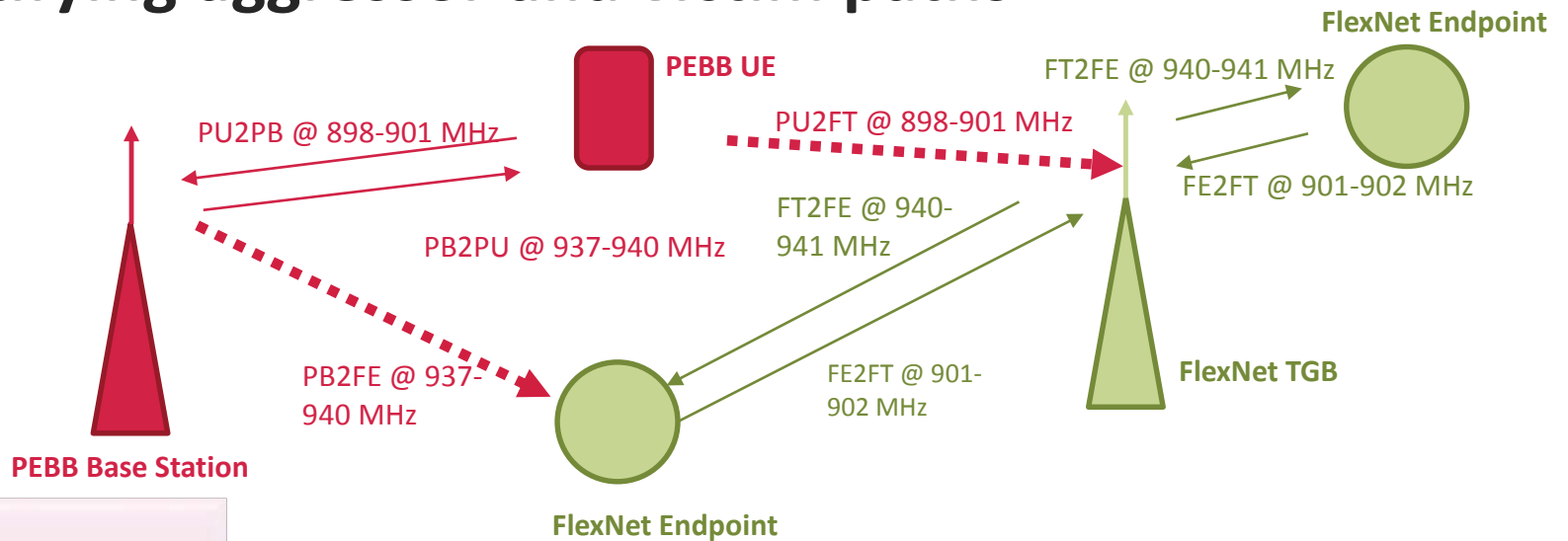


## 5. Identifying interference modes

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# Identifying aggressor and victim paths



**Key**  
**PB:** PEBB Base Station  
**PU:** PEBB UE  
**FT:** FlexNet TGB  
**FE:** FlexNet Endpoint

—→ PDV wanted path  
 - - - - -→ Aggressor path from PDV  
 —→ FlexNet wanted path

- Wanted and interfering paths are shown above as a basis for identifying the key interference modes

## Key interference modes

- Two key interference modes have been identified and are analysed in this slidepack:


Link direction	Aggressor path	Victim path	Description	Remarks
Uplink (UL)	PU2FT	FE2FT	PDV UE Tx to FlexNet TGB Base Rx	Degrades performance of all Endpoint uplinks using that FlexNet TGB
Downlink (DL)	PB2FE	FT2FE (or FB2FE)	PDV Base Tx to FlexNet endpoint Rx	Impacts any endpoint in the neighbourhood of the PDV base

- In each mode interference may arise from out-of-band emissions (ACLR impact) and/or receiver blocking (ACS impact)
- While one of these effects will usually dominate, the overall impact will be additive
- This slidepack only assesses the impact of out-of-band emissions



## Interpretations of PDV's proposed emission limits

- We have found PDV's proposed emission limits to be ambiguous and potentially incorrectly calculated by PDV
- Given this ambiguity, we have analysed the interference levels according to two distinct interpretations of the OOB limits:
  - **Interpretation A:** Assume the proposed limit refers to attenuation relative to the in-band EIRP and adopt PDV's method of calculation, which adds the aggressor antenna system gain to the proposed limit.
  - **Interpretation B:** Assume the proposed limit refers to attenuation relative to the in-band ERP and that the limit refers to the emitted power, so the aggressor antenna system gain is irrelevant.
- The sections which follow analyse the outcome according to both interpretations

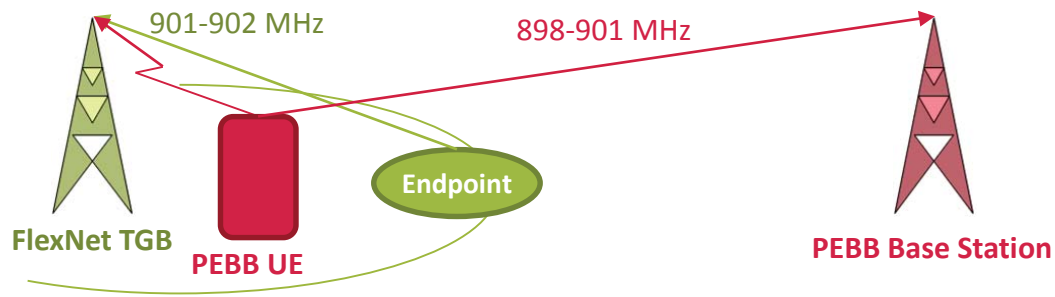


## **6. Interference mode PU2FT (Uplink PDV mobile to FlexNet base station) - Interpretation A**

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## Scenario PU2FT



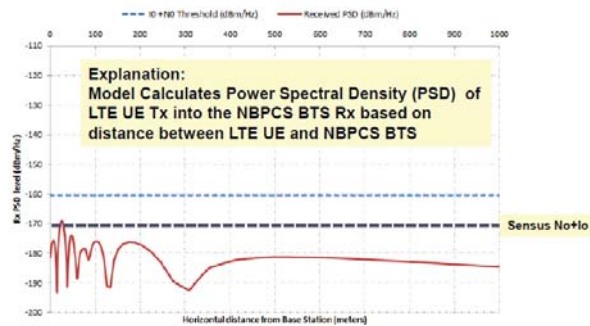
- An endpoint is at the cell edge of a FlexNet TGB (Tower Gateway Basestation)
- One (or multiple) PEBB UE is (are) nearby FlexNet TGB, and at the edge of the PEBB Base station's coverage area, thus transmitting at full power
- Degrades performance of all Endpoint uplinks using that FlexNet TGB

# PDV analysis of interference mode PU2FT

- PDV have analysed this mode and have provided a spreadsheet-based model to represent their calculations [1]
- The result of their analysis for the PSD of the LTE UE as received at the FlexNet TGB receiver is shown below [2]
- Also shown is a Real Wireless calculation based on our own model using the same parameters. This result matches closely to the PDV calculations
- PDV have compared with a -160dBm/Hz threshold. Sensus have proposed a -170dBm/Hz threshold, which would be breached by a UE at a distance of around 29m according to PDV's own calculations

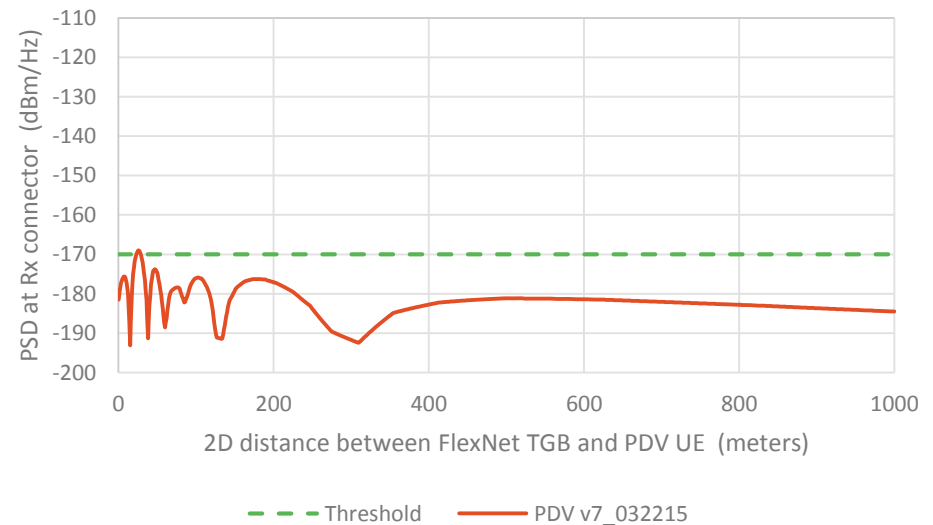
## PDV calculations

### UE OOB Filter Resolution Specification



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## Real Wireless calculations based on PDV parameters



[1] Sensus\_Coexistence Analysis\_v7\_032215

[2] PDV ex parte notice RM-11738 03-25-2015

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Real Wireless agrees with the calculation methodology proposed by PDV

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# PDV's proposals based on their modelling

- Based on their calculations, PDV have proposed that UL emissions for each UE would be attenuated by at least  $55 + 10\log(P)$  in a 30 kHz segment and have referenced the FCC rule section 90.691 [1] for this
- We understand P in this expression to represent the total in-band emission power of the UE, P where P is in watts
- It is not clear from PDV's proposals whether this is intended to relate to an EIRP limit or an ERP limit: in the proposed rules [3] neither is specified. In PDV's calculations they have assumed EIRP.
- We have therefore analysed the impact based on two potential interpretations:
  - **Interpretation A: The proposed emission limit is specified as EIRP**  
In this case the proposed emissions are -25 dBm/30 kHz EIRP
  - **Interpretation B: The proposed emission limit is specified as ERP**  
In this case the proposed emissions are -25 dBm/30 kHz ERP
- The proposed emission limit for any given value of P can be compared with the 3GPP out of band emission specification [2] which is -13 dBm/30kHz. In 3GPP this is input power to the antenna, so the actual emissions would depend on the UE antenna gain/feeder loss.

## Comments:

- Sensus systems operate in channel bandwidths as narrow as 1.6 kHz, so measuring in a 30kHz segment may not protect the base station receiver if the emissions vary significantly within the 30kHz range
- PDV have not provided any suggestion as to the measurement conditions under which these limits are to be reached. We have reviewed FCC test results for several popular LTE phones (see Annex) and have determined that **it is essential that tests be made with both full bandwidth operation and with a single resource block active**: the latter case usually produces around 7 dB higher out of band emissions

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## Proposed Technical Specifications - Emissions

### UPLINK – Portables, Fixed Endpoints, Mobiles

- On any frequency outside 898-901MHz (UL) emissions shall be attenuated below the transmitting power (P) by a factor of at least  $55 + 10\log(P)$  dB in a 30kHz segment

### § 90.1419 Emission limitations.

For operations in the 898-901/937-940 MHz band, the power of any emission outside a licensee's frequency band(s) of operation shall be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in watts, in accordance with the following:

...

- (b) On all frequencies between 898-901 MHz, by a factor not less than  $55 + 10 \log(P)$  dB in a 30 kHz band segment, for mobile stations and portable stations.

## Real Wireless has reservations as to:

- the intended emission specification (EIRP or ERP)
- the level to be protected,
- the bandwidth in which the emission level is specified,
- the lack of clarity regarding the relevant measurement conditions

[1] [FCC 47 CFR 90.691](#)

[2] 3GPP TS 36.101

[3] PDV proposed 900 MHz PEBB Allocation rules - 3 May 2015



# Real Wireless determination of coexistence parameters

- We have reviewed each of the parameters which PDV has used in their calculations
- Where we believe the parameters are incorrect or inappropriate we have applied more appropriate values according to two cases:
  - 1) A **challenging** case, based on realistic but challenging parameters
  - 2) A **moderate** case, based on parameters with a higher likelihood of occurrence

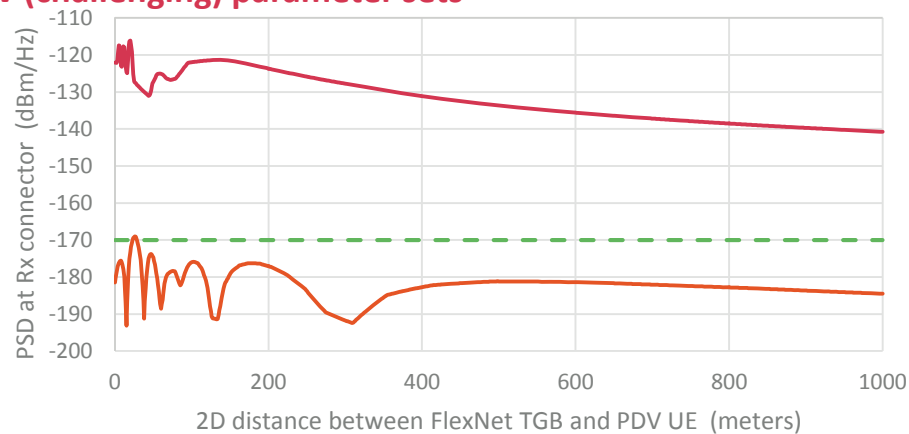
# Challenging case outcomes

## Challenging case - UL

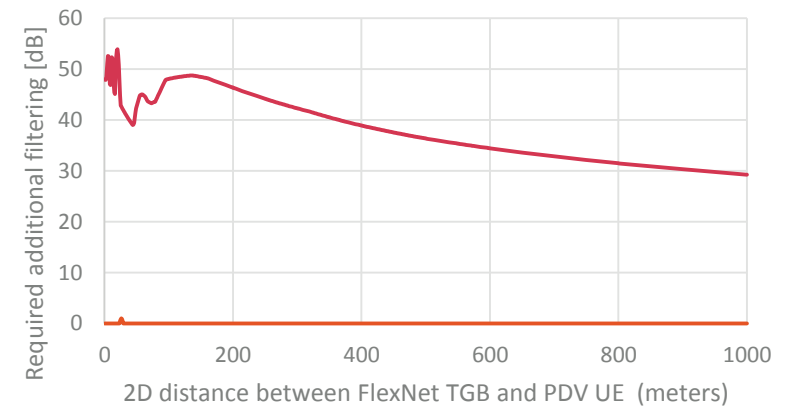
### Interpretation A

- The comparison below is based on the PDV proposed emission mask and a protection threshold at -170 dBm/Hz
- The parameters used are compared on the following slide and individually discussed in the remainder of this section

#### Comparison of interference levels based on PDV and RW (challenging) parameter sets



#### Required attenuation (additional to PDV proposal) to protect -170dBm/Hz threshold



Our view of parameters indicates that at 54dB of additional attenuation could be required to adequately protect FlexNet base stations in this challenging case

# PDV and RW challenging case parameters compared

Challenging case - UL

Interpretation A

- The calculations on the previous slide are based on the following parameters
- In the subsequent slides we examine each of the 10 issues flagged here

	Symbol	Unit	RV view	PDV v7 032215
UE transmit system	PDV Tx center frequency f	MHz	833.5	833.0
	LTE channel bandwidth including guard band BW	MHz	3	3
	Number of available RB NoRB		15	15
	PDV terminal OOB PSD immediately adjacent to channel as above in dBm/Hz P <sub>u,l</sub>	dBm/30kHz dBm/Hz	-25.2 -70.0	-25.2 -70.0
	PDV UE antenna gain G <sub>A</sub>	dBi	0.0	0.0
	PDV UE body loss G <sub>B</sub>	dB	0.0	10.0
	LTE UE Power back off PC	dB	0.0	9.0
	Effect of UE power control on OOB PSD $\Delta$		0.0	1.0
	UE cable loss G <sub>C</sub>	dB	0.0	4.0
	No. of simultaneously transmitting PDV UE NoUE		15.0	1.0
TBG receive system	OOB ERP density	dBm/Hz	-58.2	-93.0
	Thermal noise PSD	dBm/Hz	-174	-174
	FlexNet TBG noise figure	dB	4	4
	Thermal noise PSD at Rx input	dBm/Hz	-170	-170
	Environmental noise margin	dB	2	9.5
	Thermal noise PSD at Rx input, incl env. noise	dBm/Hz	-168	-161
	FlexNet TBG antenna gain	dBi	12.15 BCD-87010-EDIN-6-25	12 BCD-87010-EDIN-6
Other parameters	FlexNet TBG antenna pattern			
	FlexNet TBG height	feet	60	147.6
	FlexNet Endpoint height h <sub>b</sub>	m	18.29	45.00
	FlexNet Endpoint height h <sub>m</sub>	m	1.5	1.5
	Median propagation model	Free space		W-ILOS (slant distance)
	FlexNet TBG mechanical downtilt	deg	0	0
	Max attenuation due to V antenna pattern SLA <sub>v</sub>	dB	20	993

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# UE antenna gain and body loss

- PDV have assumed that the combination of the UE antenna gain and the head/body loss produce a composite gain of **-10dBi** citing FCC 12-151 Para. 142
- For standard UEs in the form of phones it is usual to assume an antenna gain of around 0dBi (see for example ITU-R and 3GPP system simulation assumptions [1][2][3])
- Body loss is entirely dependent on the way in which the UE is held, and on the orientation of the user with respect to the Flexnet system. Also if the UE is not already at its maximum transmit power, the body loss will cause the transmit power to increase, negating the impact of the loss. It cannot be relied upon to provide protection against interference.
- Hence our view is that a more appropriate value for the composite loss is **0dBi**
- We note however that UEs may not be smartphones, but could be for example consumer CPE intended for rural broadband applications. This can have an antenna gain as high as +10dBi, zero body loss and a high elevation, so our view by no means represents a worst case

[1] ITU-R Rep. M.2135-1 "Guidelines for evaluation of radio interface technologies for IMT-Advanced

[2] 3GPP TR 25.816, "UMTS 900 MHz Work Item Technical Report"

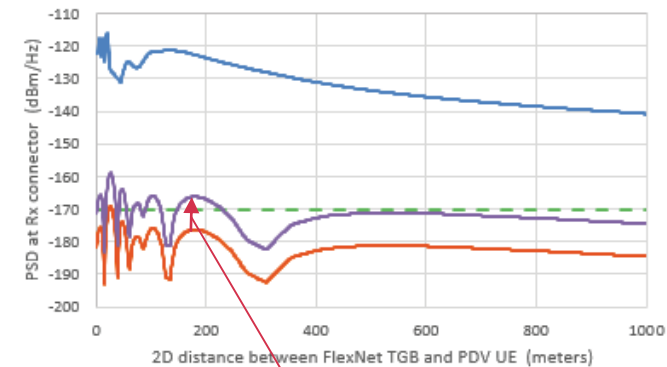
[3] 3GPP TR 36.942, "Radio Frequency (RF) system scenarios"

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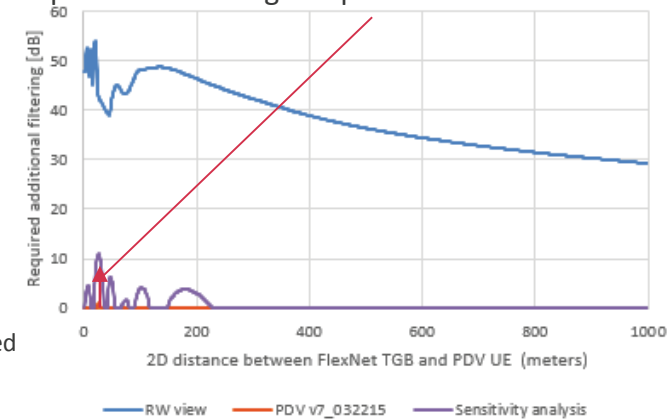
Body loss has been overestimated: Impact of correcting this: +10dB worse interference

Challenging case - UL

Interpretation A 1



Impact of correcting this parameter in PDV's calculations



# LTE UE power backoff

- PDV have assumed that the transmit power of the UE is reduced by **9dB**, citing “95% point of CSMAC WG-1 CDF curve for Suburban ”
- It appears that the reference is intended to be to [1]
- This report relates to sharing studies between terrestrial LTE UEs and meteorological satellites, whose receiver sees cumulative interference from UEs distributed over a wide area. We have several concerns with this approach:
  - The calculations relating to the statistics of UEs distributed over a wide coverage area and many cells, not to the power which may be encountered by an individual UE at a particular specific location. Such statistics are irrelevant to the analysis of an individual path between a specific aggressor UE and its victim
  - PDV have chosen the suburban curve. Many FlexNet systems operate in rural areas. The rural backoff value is closer to 2dB
  - PDV have chosen the 95% probability level. In order to protect FlexNet base stations we need to consider that a PDV UE may not be mobile, but could be permanently located close to a FlexNet TGB, so we are concerned with UEs at or near their maximum transmit power
  - Hence we believe it is appropriate to evaluate interference based on **0dB backoff**

[1] NTIA CSMAC WG-1 Final Report [link](#)

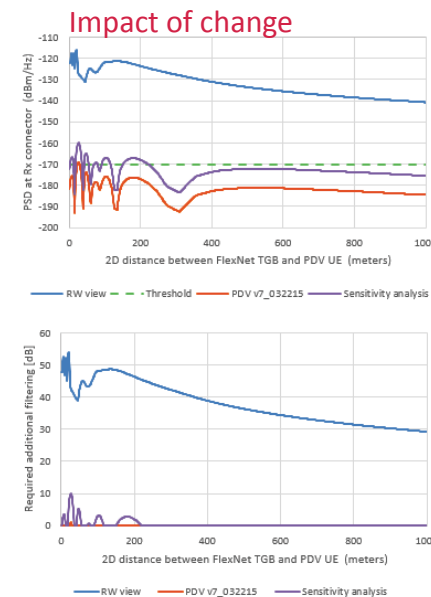
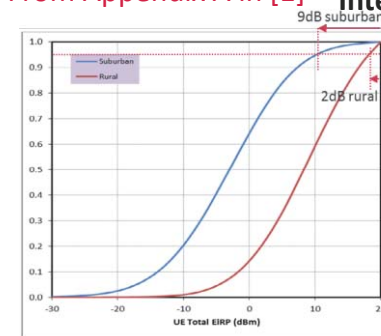
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Impact of correcting this: +9dB worse interference

## Challenging case - UL

From Appendix A in [1] Interpretation A

2



# Effect of UE power control on OOB

Challenging case - UL

Interpretation A

3

- PDV have assumed that UE out of band emissions reduce by **1dB** for every dB of reduction in fundamental power as a result of power control
- No reference is cited for this behaviour
- 3GPP (and FCC) specifications for OOB relate to an absolute power level, and do not specify a reduction with fundamental power
- It is possible that some OOB sources in some UEs might reduce with power control: however OOB can also be caused by sources such as spurious emissions from local oscillator leakage and wideband noise from linearised PAs, neither of which is likely to scale with the fundamental power
- So we believe it is inappropriate to assume that OOB emissions reduce with power control, and this parameter should be set conservatively to **0dB**
- This parameter works together with the previous parameter (power backoff assumption (2)). So even if our view on power backoff is not accepted, the impact of the power backoff on OOB would be negated and the same 9dB increase in interference would be experienced.

Impact of correcting this: +9dB worse interference (taken together with issue (2))

## “NB-BTS cable loss”

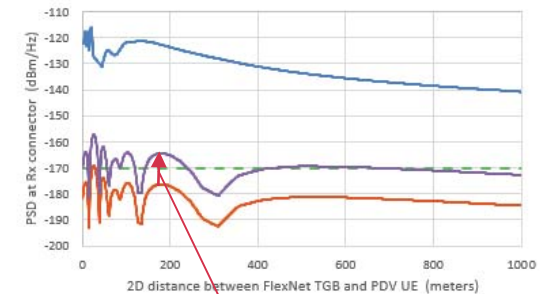
- PDV’s calculation includes a parameter called “NB-BTS Cable Loss”, set to a value of **4.0 dB**. No reference source for this parameter is provided
- In PDV’s model, this parameter directly reduces the level of the UE OOB emissions, so it appears in fact to be applied as a UE feeder loss
- The UE feeder loss would in practice be treated as part of the definition of the UE antenna gain, with no separate parameter necessary
- It appears therefore that PDV have mistakenly included this parameter and it should be removed or set to **0 dB** to correctly determine the UE OOB level

PDV have mistakenly included a parameter which is not relevant.  
Impact of correcting this: +4 dB worse interference

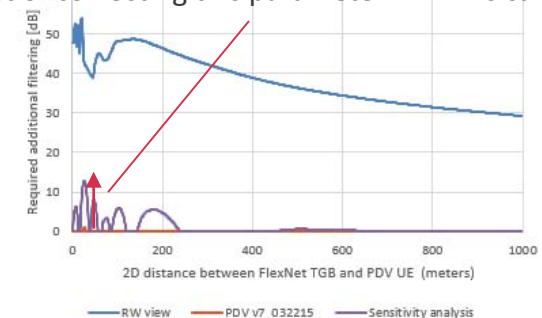
# No of simultaneously transmitting PDV devices Interpretation A

5

- PDV have assumed that only a single UE is transmitting in the channel, although they have included a parameter to set the numbers of UEs in their model
- In a 3 MHz LTE channel there are 15 individually addressable resource blocks, in each of which the base station (eNB) can schedule a single UE. In this situation each UE can simultaneously transmit at full power, creating a cumulative interference level 15x (12dB) greater than analysed



Impact of correcting this parameter in PDV's calculations



PDV have not included the effect of multiple UEs.  
Impact of correcting this: +12 dB worse interference

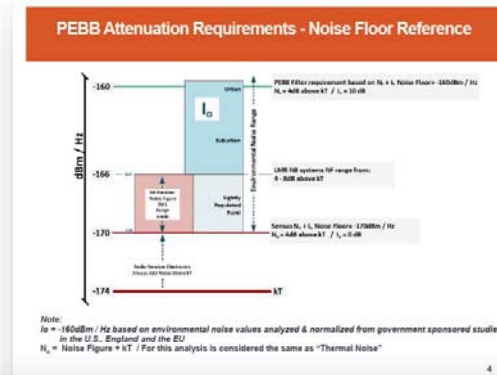
# Environmental noise margin (1)

- The basic noise floor seen at a Sensus base station is at thermal noise PSD ( $kT = -174\text{dBm/Hz}$ ) plus the base station system noise figure (4dB based on Sensus data) –  
i.e. **-170 dBm/Hz**
- The noise floor *may* be raised at individual sites by environmental noise
- PDV has included a noise margin of 10dB, resulting in a 9.5 dB noise rise to **-160.5 dBm/Hz**. This is based on their reading of a collection of studies which made in various environments, but they note that: “studies...were difficult to find...deliver values from a limited amount of samples...had to be extrapolated” suggesting a low confidence in their chosen value.
- We note that environmental noise arises in practice from specific sources which vary substantially with location, time and frequency. At any given base station the environmental noise may be much lower than these values.
- In contrast to the generalised data which PDV have used, Sensus have made explicit measurements at a several base stations over several years

Challenging case - UL

Interpretation A

6



## -160dBm Reference Noise Floor – $N_0 + I_0$

- IEEE 473 1985 - IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz)
- World Meteorological Organization COMMISSION FOR BASIC SYSTEMS STEERING GROUP ON RADIO FREQUENCY COORDINATION Results of Ambient RF Environment and Noise Floor Measurements Taken in the U.S. in 2004 and 2005
- Man Made Noise in Our Living Environment International Union of Radio Science No. 334, September 2010
- CEPT REPORT 19 - Revision 10/30/08 Report from CEPT to the European Commission in response to the mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS

Note: In their model PDV also cite TIA-TSB-88.2-D

## Note:

Studies to determine the -160dBm reference noise floor were difficult to find. Publically available studies deliver mean or median values from a limited amount of samples and some cases had to be extrapolated for this analysis to develop a generalized threshold for use in modeling and determining a baseline ceiling reference  $N_0 + I_0$  value.

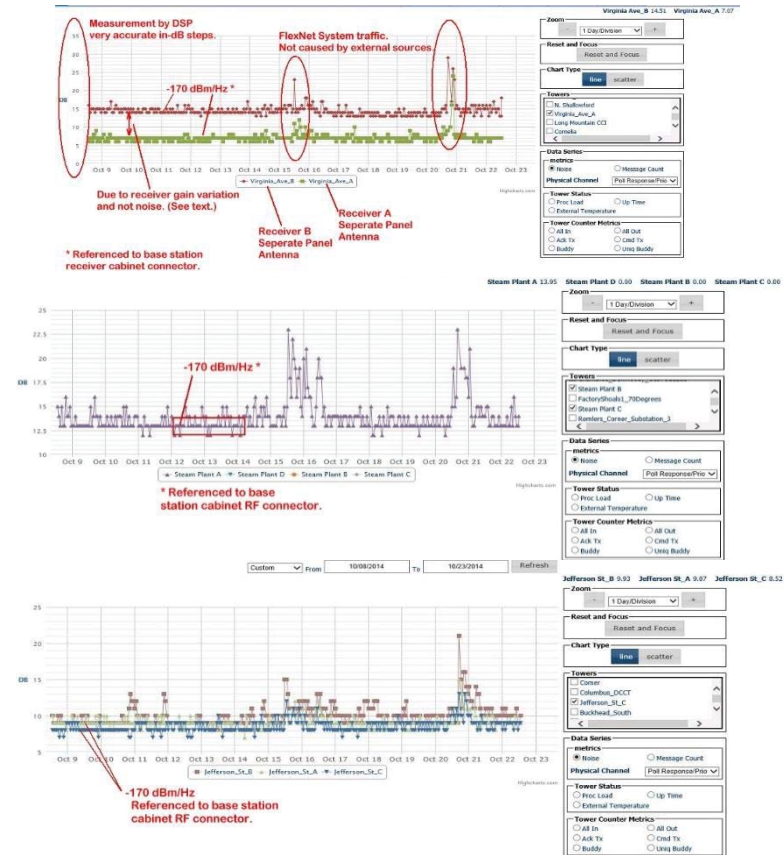
# Environmental noise margin (2)

- Shown opposite are measurements by Sensus at FlexNet base station receivers at three sites in downtown Atlanta
- These show minor (**1-3 dB**) excursions from a -170dBm/Hz noise floors (the larger peaks are due to active traffic, not noise), despite the urban environment – rural environments would be expected to exhibit less noise
- Sensus report that they also have data from paging companies' base stations from '03, '04 and '05. They have seen no significant change in the noise floor environment over the last 10-13 years

Challenging case - UL

Interpretation A **6**

## Environmental noise measurements in Downtown Atlanta



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## Environmental noise margin (3)

- Hence we consider that PDV have applied an excessive allowance for environmental noise, based on unsuitable data, and suburban/urban environments rather than rural cases
- Even where environmental noise does occur, interference from PDV UEs will be additive, degrading the overall system reliability and capacity
- Hence we believe it is appropriate to protect FlexNet base stations at their noise floor of **-168 dBm/Hz**, not the PDV suggestion of **-160.5 dBm/Hz**

- PDV's suggestion is based on inadequate data and inappropriate environments and is out of line with the real-world environment encountered by FlexNet
- Impact of correcting this: 7.5 dB worse interference impact (through lowered protection threshold)

# Base station antenna radiation pattern and gain

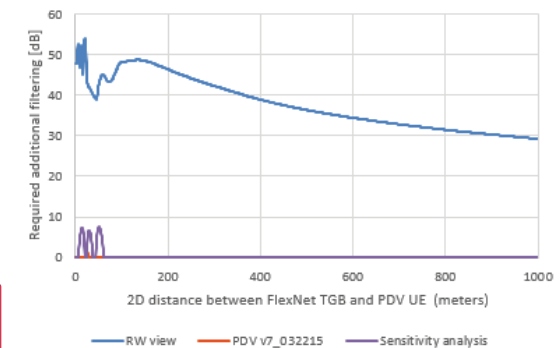
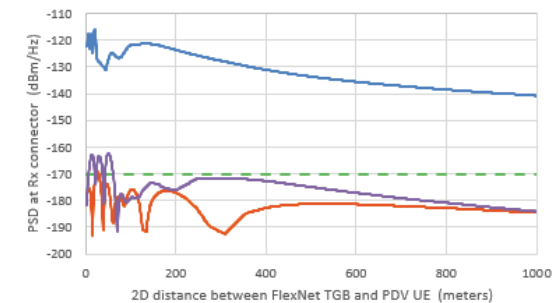
Challenging case - UL

Interpretation A

7

- In the first version of their model [1] PDV quoted antenna pattern BCD-87010-EDIN-6: we have checked the manufacturer's website for this and compared: the pattern is entirely different from that used by PDV – this appears to be a mistake
- In the newer version of the model [2] PDV quote antenna type BCD-87010-EDIN-1-25, but the pattern data used is identical to the previous version: we cannot find this on the manufacturer's website
- The most commonly used patterns in the FlexNet network are the BCD-87010-25 series model: we propose to use the BCD-87010-6-25 which has 6 degrees of electrical downtilt
- While the antenna gain is unchanged, the increased downtilt results in peaks of interference around 7dB higher and extended over a greater ranges of distances

PDV appear to have used the wrong antenna radiation pattern: a realistic pattern increases short-range interference by around 7 dB



# Base station antenna height

- PDV have assumed a base station antenna height of **148'** (45m)
- Analysis of the actual antenna heights of FlexNet base stations shows that:
  - The median (50%) antenna height is between 110'-120'
  - Around 20% antennas are below 80'
  - Around 10% of antennas are below 60'
- PDV have chosen a non-typical height
- Lower antenna heights reduce the path loss to the UE, increasing the maximum interference level
- In order to protect most base stations , we select the 10% value of **60'**
- The impact of this change is shown opposite

PDV have overestimated the height for the FlexNet antenna  
Correcting this increases the interference level by up to 10 dB

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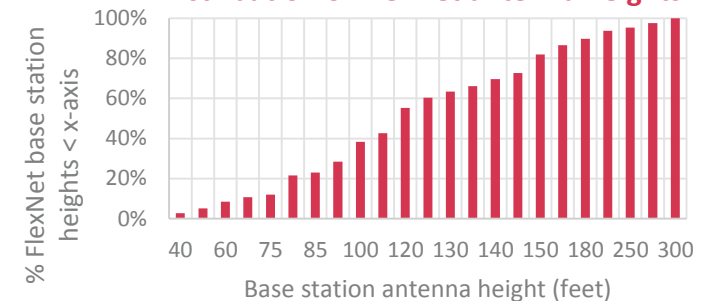
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## Challenging case - UL

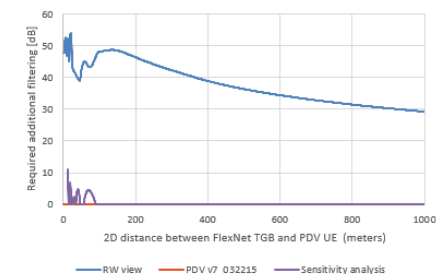
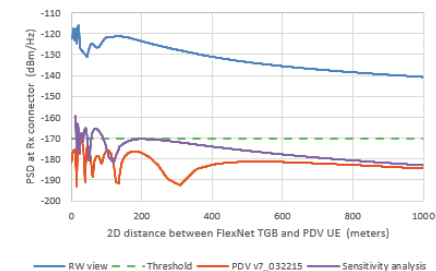
8

### Interpretation A

#### Distribution of FlexNet antenna heights



#### Impact of changing height from 148' to 60'



# Propagation model (1)

Challenging case - UL

Interpretation A

9

- PDV have used the **Walfisch-Ikegami LoS model** in their calculations. They have made provision for calculations using the free space loss, but have not applied this and the model does not appear to function correctly for this case (it reverts to the “WI-LOS” model even when “Free Space Model” is selected)
- The Walfisch-Ikegami model is a theoretically-based model with empirical extensions, published by a European research project COST-231 [1]. The full text of the model description shown opposite.
- When a line-of-sight path is present and the distance is greater than 20m, the model reverts to an empirical adjustment intended to represent the presence of scattering within an urban canyon environment
- It has several key limitations in this applications:
  - It is not defined for use below 20m (it matches free space loss at that range, but is not intended to be used below that range)
  - It is not applicable in locations represented by anything other than a street canyon, which is an environment rich in multipath and urban furniture features.
  - It is only intended for base station heights below 50m
- For short distances, propagation models converge to free space loss formulation and parameters. The free space loss model is commonly used in co-existence studies to model short and line-of-sight interference paths
- We therefore recommend the use of the **free space loss model** at all ranges where there is potential for a line-of-sight
- We note that indeed at short ranges <20m PDV have adopted the free space model (which is not specified by the Walfisch-Ikegami model)

[1] “Digital mobile radio towards future generations”, COST action 231, 1999

## The Walfisch-Ikegami LoS model

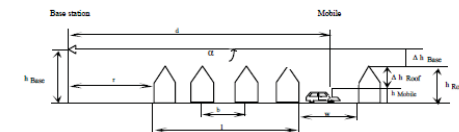


Fig 4.4.1 Typical propagation situation in urban areas and definition of the parameters used in the COST-WI model and other Walfisch-type models [24], [45], [52].

The model distinguishes between line-of-sight (LOS) and non-line-of-sight (NLOS) situations. In the LOS case -between base and mobile antennas within a street canyon - a simple propagation loss formula different from free space loss is applied. The loss is based on measurements performed in the city of Stockholm:

$$L_b(\text{dB}) = 42.6 + 26 \log(d/\text{km}) + 20 \log(f/\text{MHz}) \quad \text{for } d \geq 20 \text{ m} \quad (4.4.5)$$

where the first constant is determined in such a way that  $L_b$  is equal to free-space loss for  $d = 20 \text{ m}$ . In the NLOS-case the basic transmission loss is

## Applicability of Walfisch-Ikegami LoS model

The COST-WI model is restricted to:

$f$ :	800 ... 2000 MHz
$h_{\text{Base}}$ :	4 ... 50 m
$h_{\text{Mobile}}$ :	1 ... 3 m
$d$ :	0.02 ... 5 km

## Propagation model (2)

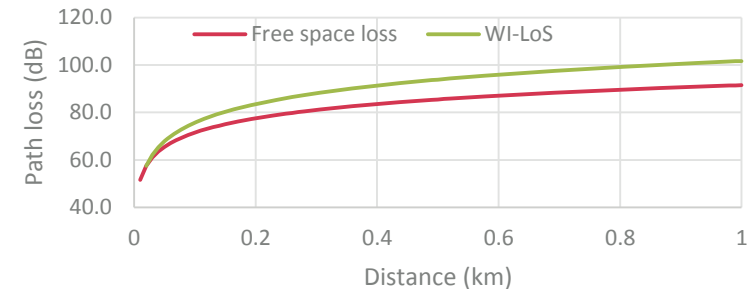
- Since Walfisch-Ikegami exceeds the free space loss model at all ranges > 20m, it risks understating the extent of interference
- It has a small (1.4 dB) impact on interference at a range of around 30 m taken on its own
- However when taken together with the change to the antenna pattern the impact is compounded and results in a 3.5 dB increase in interference (on top of the 7 dB due to the antenna change)

Challenging case - UL

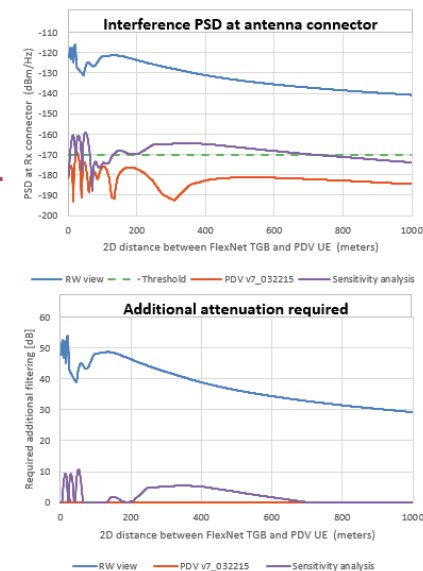
9

Interpretation A

Comparing the Walfisch-Ikegami LoS and free space models



Combined impact of propagation model and antenna pattern



# Maximum attenuation due to antenna pattern

- Antenna patterns are measured in anechoic chambers, which exhibit no multipath propagation
- In practical environments even small amounts of multipath can substantially reduce the depth of antenna pattern nulls (see example from [1]), so these should not be relied on to provide interference protection in particular directions
- PDV has **not considered** this effect
- In order to deal with this it is typical to cap the attenuation from the antenna at some level, typically around 20 dB (see [2, 3])
- The impact is to significantly increase the level of interference at the shortest ranges, resulting in an extra 2.5 dB attenuation

[1] "Antenna pattern measurement technique using wideband channel profiles to Resolve Multipath Signal Components", Newhall & Rappaport, AMTA 19<sup>th</sup> symp. Boston, Nov. 1997

[2] 3GPP TR 36.942

[3] 3GPP TR 36.814

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## Theoretical pattern

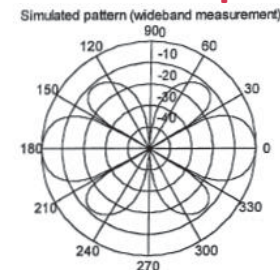


Figure 10. This simulated pattern represents the use of a wideband profile to plot the true antenna pattern by using only the LOS component. (dB vs.  $\theta^\circ$ )

## Practical pattern [1]

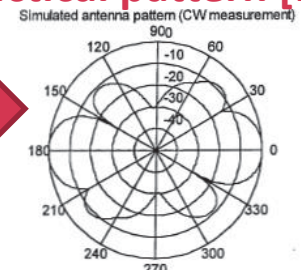
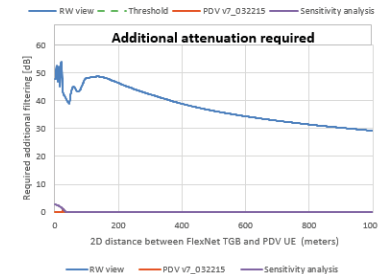
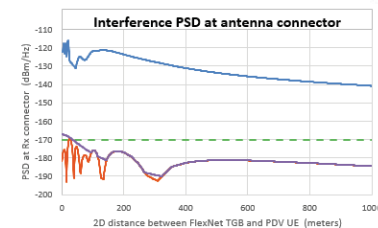


Figure 11. The effect of a single multipath component is seen by the distortion of lobes and filling of nulls compared to the true pattern illustrated in Figure 10. (dB vs.  $\theta^\circ$ )

Real world



# Summary of differences – challenging case

- We believe PDV has understated the impact of interference due to the following inappropriate parameter choices:

#	Parameter	Comment on PDV assumptions	Impact of each correction on interference (relative to RW challenging case):
①	UE antenna gain and body loss	Body loss does not always protect from interference	+10dB
②	UE power back off	PDV assumed a statistical backoff based on UE mobility	+9dB
③	Effect of UE power control on OOBE	PDV assumed power control impacts on OOBE by 1dB per dB	
④	“UE cable loss”	Appears to be mistakenly included	+4dB
⑤	Number of simultaneous UE	Assumed only 1 UE active	+12dB
⑥	Environmental noise margin	Assumed 9.5 dB noise rise from reference sources, no measurements	+7.5 dB
⑦	Flexnet TGB antenna gain & pattern	Used an unrealistic antenna pattern	+7 dB
⑧	Flexnet TGB antenna height	Overestimated antenna height	+10 dB
⑨	Propagation model	Propagation model used is for different environment	+3.5 dB
⑩	Maximum antenna attenuation	No consideration of impact of real environment on nulls	+2.5dB
	<b>Overall</b>	<b>Effects are not simply additive</b>	<b>~50-55dB</b>

# Moderate case parameters

Moderate Case - UL

Interpretation A

#	Parameter	Unit	PDV Parameters	RW Challenging case parameters	RW moderate case parameters
1	UE antenna gain and body loss	dBi	-10.0	0	-3.0
2	UE power back off	dB	9.0	0	3.0
3	Effect of UE power control on OOBE	dB per dB	1.0	0	1.0
4	PDV eNodeB cable loss		4.0	0	0.0
5	Number of simultaneous UE	# UEs	1.0	15	3.0
6	Protection level	dBm/Hz	-160.0	-170	-168.0
7a	Flexnet TGB antenna boresight gain	dBi	12.2	12.2	12.2
7b	Flexnet TGB antenna pattern		Unknown pattern per PDV model	Amphenol, BCD-87010-6-25 (6 elec. downtilt)	Amphenol BCD-87010-3 with 3 degree electrical downtilt
8	Flexnet TGB antenna height	feet	147.6'	60'	110'
9	Propagation model		W-I LOS	Free space	Free space
10	Maximum antenna attenuation	dB	Unlimited	20	Unlimited

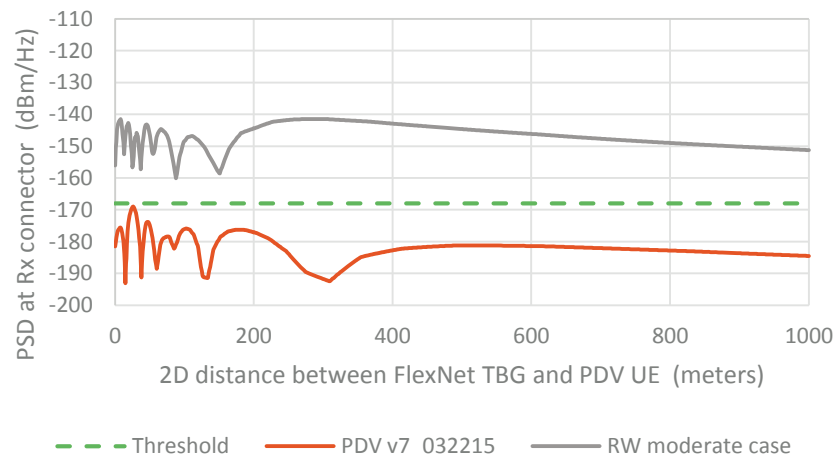
# RW moderate case: coexistence parameters

Moderate Case - UL

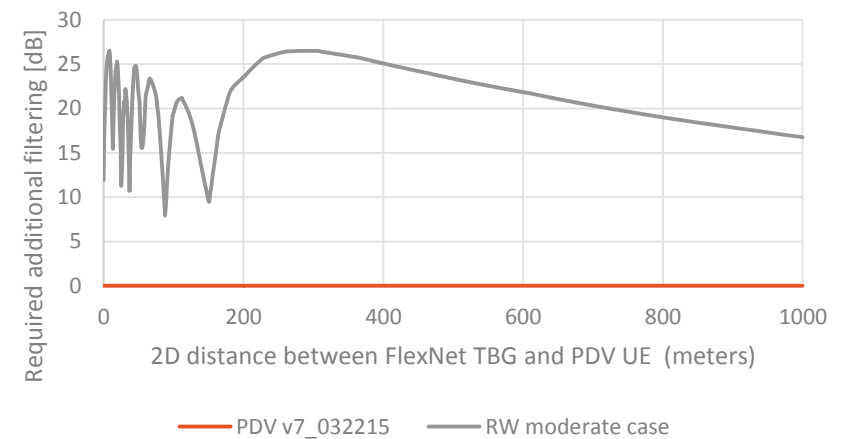
Interpretation A

- We have conducted the RW moderate case analysis. The PDV case results are also shown below.

## Comparison of interference levels between PDV and proposed moderate case



## Required attenuation (additional to the threshold) to protect -168dBm/Hz threshold



Our view of parameters indicates that some 27 dB of additional attenuation could be required to adequately protect FlexNet base stations in this moderate case

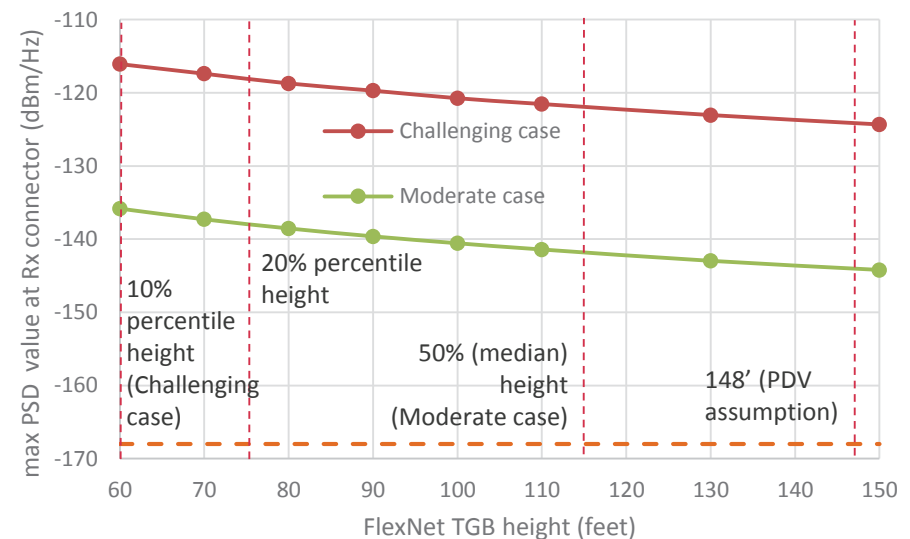
# Effect of TGB antenna height


Moderate Case - UL

Challenging case - UL

Interpretation A

- We have varied the height of the Sensus TGB base station to determine the sensitivity to this parameter
- The graph shows the value of the highest PSD encountered at any distance for a given TGB antenna height
- There is around 10 dB of variation between the PDV assumption and our challenging case (which represents protection of ten percent of all Sensus TGBs)
- There is around 5dB of variation between our moderate and challenging cases
- This points to the potential for a site-specific protection level
- However in all cases the PSD remains above the required protection level





## **7. Interference mode PU2FT UL (PDV mobile to FlexNet base station) - Interpretation B**

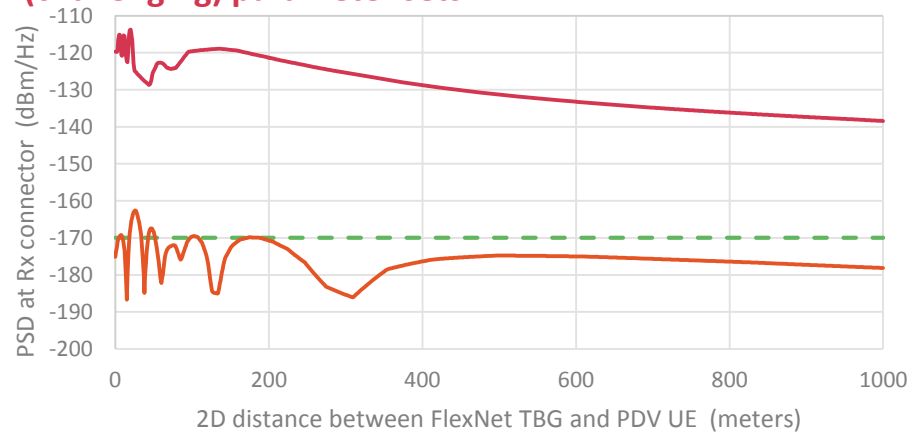
# Challenging case outcomes

## Challenging case - UL

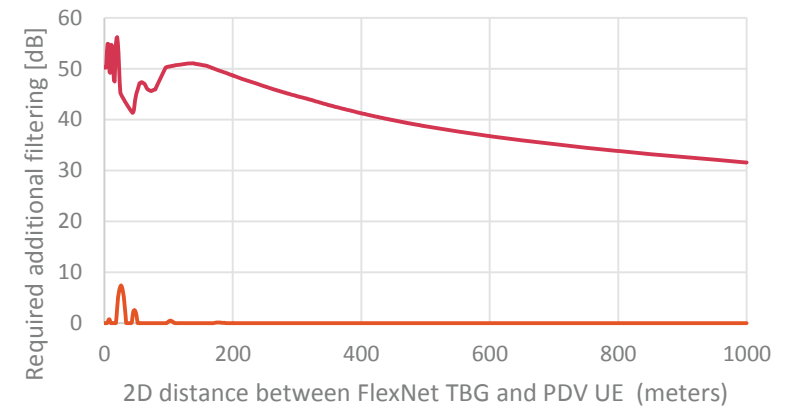
### Interpretation B

- The comparison below is based on the PDV proposed emission mask and a protection threshold at -170 dBm/Hz
- The parameters used are compared on the following slide and individually discussed in the remainder of this section

#### Comparison of interference levels based on PDV and RW (challenging) parameter sets



#### Required attenuation (additional to the -170 dBm/Hz threshold)



Our view of parameters indicates that 56dB of additional attenuation could be required to adequately protect FlexNet base stations in this challenging case

# Challenging case and Moderate case parameters

Interpretation B

#	Parameter	Unit	PDV Parameters	RW Challenging case parameters	RW moderate case parameters
1	UE antenna gain and body loss	dBi	-10.0	0	-3.0
2	UE power back off	dB	9.0	0	3.0
3	Effect of UE power control on OOBE	dB per dB	1.0	0	1.0
4	PDV eNodeB cable loss		4.0	0	0.0
5	Number of simultaneous UE	# UEs	1.0	15	3.0
6	Protection level	dBm/Hz	-160.0	-170	-168.0
7a	Flexnet TGB antenna boresight gain	dBi	12.2	12.2	12.2
7b	Flexnet TGB antenna pattern		Unknown pattern per PDV model	Amphenol, BCD-87010-6-25 (6 elec. downtilt)	Amphenol BCD-87010-3 with 3 degree electrical downtilt
8	Flexnet TGB antenna height	feet	147.6'	60'	110'
9	Propagation model		W-I LOS	Free space	Free space
10	Maximum antenna attenuation	dB	Unlimited	20	Unlimited

# PDV and RW challenging case parameters compared

Interpretation B

- The calculations on the previous slide are based on the following parameters
- In the subsequent slides we examine each of the 10 issues flagged here

	Symbol	Unit	Value	
			RW view	PDV v7_032215
UE transmit system	PDV Tx center frequency $f$	MHz	839.5	839.0
	OOB attenuation factor	dB	55	55
	PDV terminal OOB PSD immediately adjacent to channel	dBm/30kHz ERP	-55.0	-55.0
				Incorrectly stated +10log(P)
				Equivalent of -20dBm/100kHz from FCC 47 CFR 90.631/CMRS BC 26
TGB receive system				
Other parameters				

## Issues with 10 parameters

- Details of our views on the following issues are available in the previous section: the same issues apply equally to this interpretation:
  - UE antenna gain and body loss
  - LTE UE power backoff
  - Effect of UE power control on OOBE
  - “NB-BTS cable loss”
  - No of simultaneously transmitting PDV devices
  - Environmental noise margin
  - Base station antenna radiation pattern and gain
  - Base station antenna height
  - Propagation model
  - Maximum attenuation due to antenna pattern

# Summary of differences – challenging case

Challenging case - UL

Interpretation B

- We believe PDV has understated the impact of interference due to the following inappropriate parameter choices:

#	Parameter	Comment on PDV assumptions	Impact of each correction on interference (relative to RW challenging case):
①	UE antenna gain and body loss	Body loss does not always protect from interference	+10dB
②	UE power back off	PDV assumed a statistical backoff based on UE mobility	+9dB
③	Effect of UE power control on OOBE	PDV assumed power control impacts on OOBE by 1dB per dB	
④	“UE cable loss”	Appears to be mistakenly included	+4dB
⑤	Number of simultaneous UE	Assumed only 1 UE active	+12dB
⑥	Environmental noise margin	Assumed 9.5 dB noise rise from reference sources, no measurements	+7.5 dB
⑦	Flexnet TGB antenna gain & pattern	Used an unrealistic antenna pattern	+7 dB
⑧	Flexnet TGB antenna height	Overestimated antenna height	+10 dB
⑨	Propagation model	Propagation model used is for different environment	+3.5 dB
⑩	Maximum antenna attenuation	No consideration of impact of real environment on nulls	+2.5dB
	<b>Overall</b>	<b>Effects are not simply additive</b>	<b>~50-55dB</b>

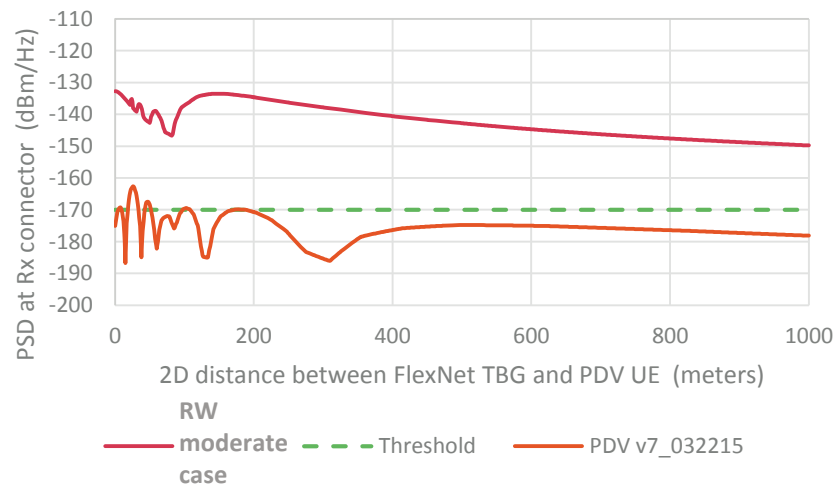
# RW moderate case: coexistence parameters

Moderate Case - UL

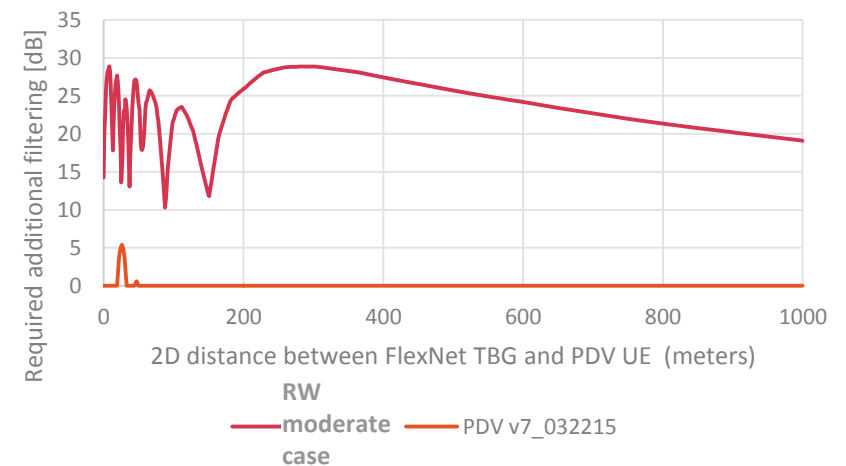
Interpretation B

- We have conducted the RW moderate case analysis. The PDV case results are also shown below.

## Comparison of interference levels between PDV and proposed moderate case



## Required attenuation (additional to the -168 dBm/Hz threshold)



Our view of parameters indicates that some 29 dB of additional attenuation could be required to adequately protect FlexNet base stations in this moderate case

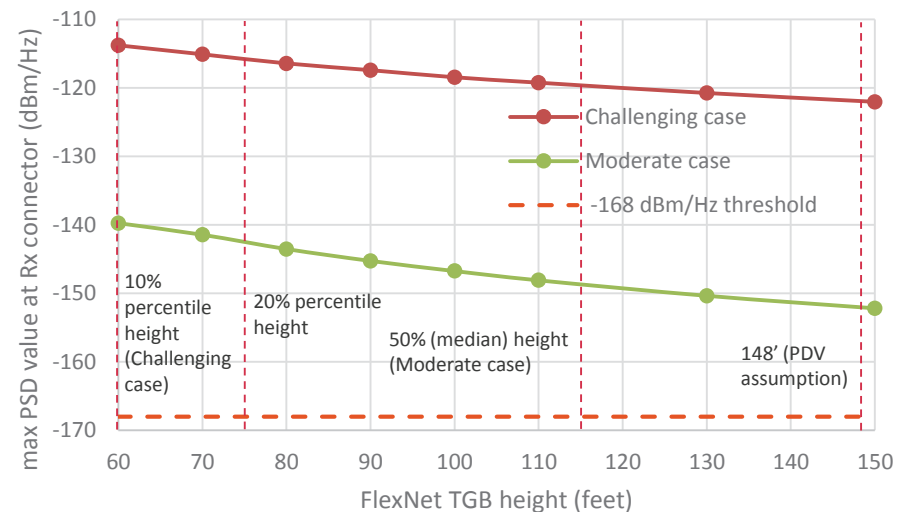
# Effect of TGB antenna height

- We have varied the height of the Sensus TGB base station to determine the sensitivity to this parameter
- The graph shows the value of the highest PSD encountered at any distance for a given TGB antenna height
- There is around 10 dB of variation between the PDV assumption and our challenging case (which represents protection of ten percent of all Sensus TGBs)
- There is around 5dB of variation between our moderate and challenging cases
- This points to the potential for a site-specific protection level
- However in all cases the PSD remains above the required protection level

Moderate Case –UL

Challenging case - UL

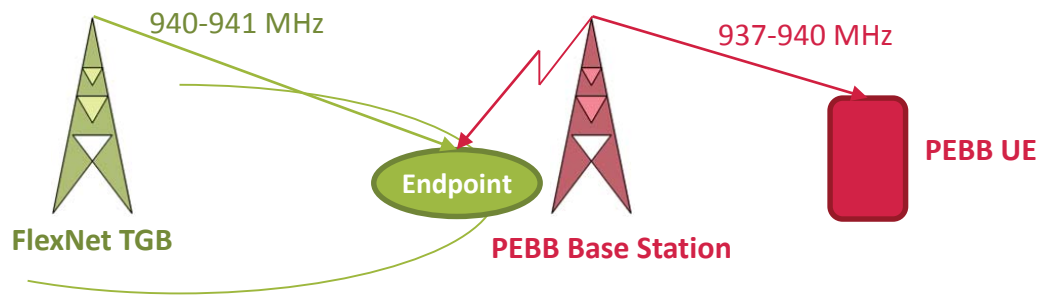
Interpretation B





## **8. Interference mode PB2FE DL (PDV base station to FlexNet endpoint) – Interpretation A**

## Scenario PB2FE

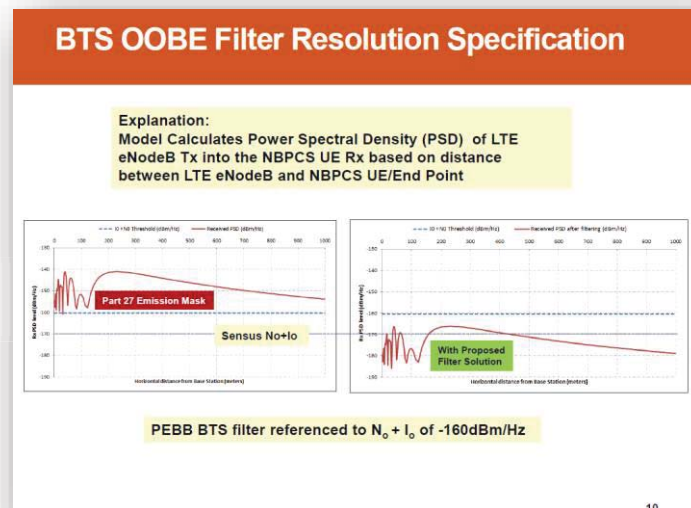


- An endpoint is at the edge of a FlexNet
- A PEBB Base Station is nearby and causes excessive interference to an endpoint Rx

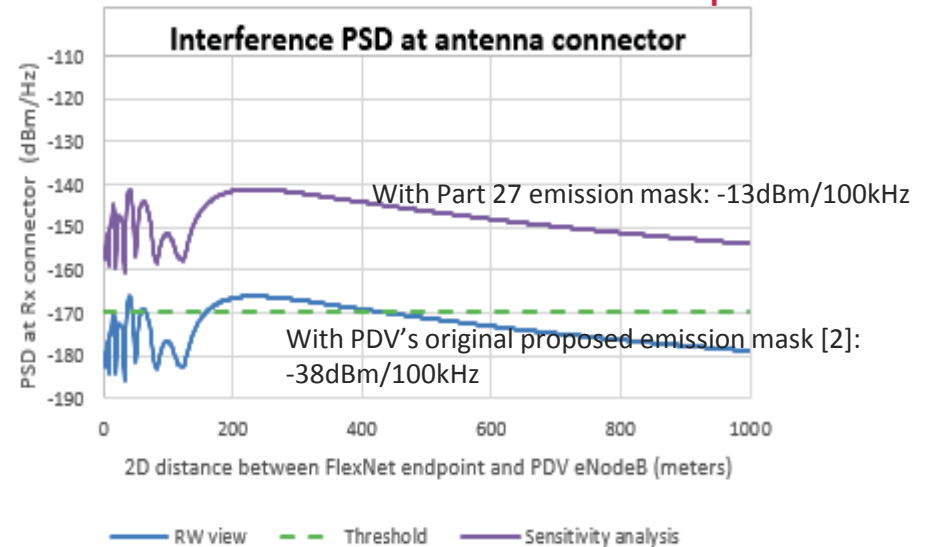
# PDV analysis of interference mode PB2FE

- PDV have analysed this mode and have provided a spreadsheet-based model to represent their calculations [1]
- The result of their analysis for the PSD of the LTE eNB as received at the FlexNet endpoint receiver is shown below [2].
- Also shown is a Real Wireless calculation based on our own model using the same parameters. This result matches closely to the PDV calculations

## PDV calculations



## Real Wireless calculations based on PDV parameters



- [1] Sensus\_Coexistence Analysis\_v7\_032215  
[2] PDV ex parte notice RM-11738 03-25-2015

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Real Wireless agrees with the calculation methodology proposed by PDV

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# PDV's proposals based on their modelling

Based on their calculations, PDV proposed in their initial ex parte filing [1] that DL emissions for each eNodeB would be attenuated by at least:

**$73 + 10\log(P)$  in a 30 kHz segment (March 25 proposal)**

which they say is 25dB lower than the FCC Part 27 specifications

Subsequently PDV revised their proposals in [2] to an attenuation of

**$55 + 10\log(P)$  in a 30 kHz segment (May 3 proposal)**

We understand that P is in watts and represents the total in-band emissions of the eNodeB

It is not clear from PDV's proposals whether this P is intended to relate to an EIRP limit or an ERP limit: in the proposed rules [2] neither is specified. In PDV's calculations they have assumed EIRP. In PDV's calculations they have also assumed that the antenna gain-feeder loss of their eNB is added to the proposed emission limit, thereby increasing the actual emissions beyond the proposed limit

We have therefore analysed the impact based on two potential interpretations:

- **Interpretation A (as per PDV's calculations) : The proposed emission limit is specified as EIRP and the eNB antenna gain-feeder loss is added to this**

In this case the proposed emissions are -43 dBm/30 kHz EIRP PLUS antenna gain of 16 dBi MINUS feeder loss of 4dB i.e. effectively

- **Interpretation B: The proposed emission limit is specified as ERP and the emission limit relates to the actual emissions, not the antenna input**

In this case the proposed emissions are -25 dBm/30 kHz ERP INDEPENDENT of the eNB antenna gain/feeder loss

We note the following:

- This is referenced to a -160.5 dBm/Hz threshold. Sensus have proposed a -170 dBm/Hz threshold. The threshold would be breached by an eNodeB at any distance, in the case of the FCC Part 27 specification, and at a distance of around 16m and 150-400m according to PDV's calculations
- Sensus systems operate in channel bandwidths as narrow as 1.6 kHz, so measuring in a 30kHz segment may not protect the Endpoint receiver if the emissions vary significantly within the 30kHz range
- Need to properly specify the eNB traffic and other measurement conditions in which this applies

Real Wireless has reservations as to the intended emission specification (EIRP or ERP) , the level to be protected and the bandwidth in which the emission level is specified

PDV initial proposal (in ex parte filing[1]):

## Proposed Technical Specifications - Emissions

### DOWNLINK – Base Station and Fixed

- On any frequency outside 937-940MHz (DL) emissions shall be attenuated below the transmitting power (P) by a factor of at least  $73+10\log(P)$  dB in a 30kHz segment

PDV proposal (in ex parte filing [2]):

(a) On all frequencies between 937-940 MHz, by a factor not less than  $55 + 10\log(P)$  dB in a 30 kHz band segment, for base and fixed stations.

[1] PDV ex parte notice RM-11738 - 25 March 2015

[2] PDV proposed 900 MHz PEBB Allocation rules - 3 May 2015



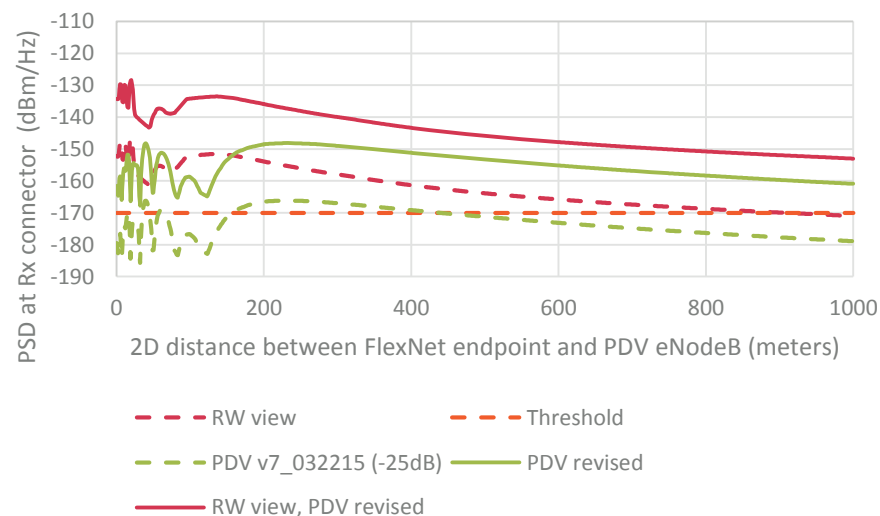
# Real Wireless determination of coexistence parameters

- We have reviewed each of the parameters which PDV has used in their calculations
- Where we believe the parameters are incorrect or inappropriate we have applied more appropriate values according to two cases:
  - 1) A **challenging** case, based on realistic but challenging parameters
  - 2) A **moderate case**, based on parameters with a higher likelihood of occurrence

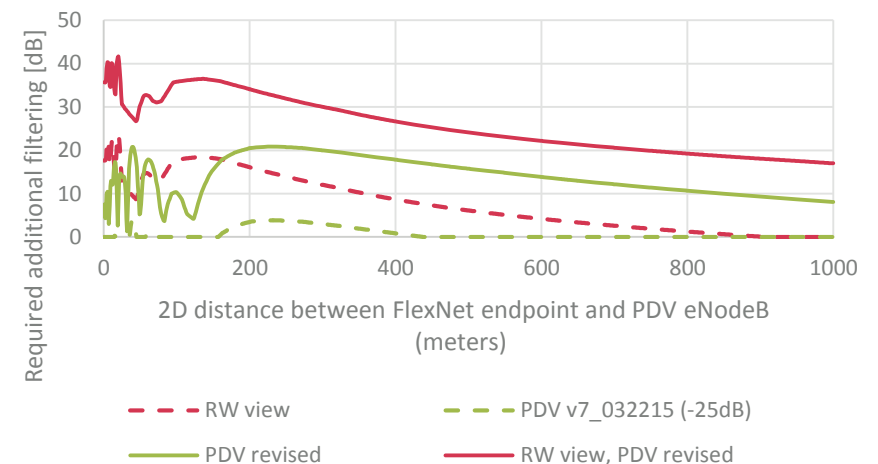
# Real Wireless challenging case outcomes

- The comparison below is based on the PDV proposed emission mask and a protection threshold at -170 dBm/Hz
- The parameters used are compared on the following slide and individually discussed in the remainder of this section

## Comparison of interference levels based on PDV and RW challenging parameter sets



## Required attenuation (additional to PDV proposal) to protect -170dBm/Hz threshold



Our view of parameters indicates that 24 dB of additional attenuation could be required to adequately protect FlexNet Endpoints given the original PDV proposal and **42 dB extra attenuation for the revised PDV proposal**

# PDV and RW challenging case parameters compared

- The calculations on the previous slide are based on the following parameters
- In the subsequent slides we examine each of the 6 issues flagged here

Challenging case - DL

Interpretation A

	Symbol	Unit	Value	Value	Comment
			RW view	PDV v7_032215 (-25dB)	
Base station (eNB) transmit system	PDV Tx center frequency f	MHz	938.5	938.0	The correct center frequency incorrectly stated
	LTE channel bandwidth including guard band BW	MHz	3	3	
	Number of available RB NoRB		15	15	3GPP TS 36.101
	PDV eNodeB OOB PSD immediately adjacent to channel as above in dBm/Hz P_1	dBm/100kHz	-38.0	-38.0	PDV's proposal FCC CFR 22.917 - 25dB
			-88.0	-88.0	
	PDV eNodeB antenna gain G_A	dBi	16.0	16.0	PDV assumes ARGUS HPX308R (2deg), which operates 1525-1710MHz
	PDV eNodeB cable loss G_C	dB	4.0	4.0	PDV's assumption
	PDV eNodeB antenna pattern		BCD-7001-EDIN-X	ARGUS HPX308R (2deg)	PDV assumes ARGUS HPX308R (2deg), which operates 1525-1710MHz
	OOB EIRP density	dBm/Hz	-76.0	-76.0	=P_1+G_A-G_C
	Thermal noise PSD	dBm/Hz	-174	-174	Constant, 10*LOG10(kT)+30
FlexNet endpoint receive system	FlexNet Endpoint noise figure	dB	4	4	Input from Sensus: Bob_Notes_For_RW No source given
	Thermal noise PSD at Rx input	dBm/Hz	-170	-170	
	Environmental noise margin	dB	2	9.5	Based on Sensus measurements TIA-TSB-88.2-D
	Thermal noise PSD at Rx input, incl env. noise	dBm/Hz	-168	-160.5	
Other parameters	FlexNet Endpoint antenna gain	dBi	0	1.15	Equivalent to -1dBd no source given
	FlexNet Endpoint cable loss	dB	0	1.9	No source given
	PDV eNodeB height	feet	60	98.4	
	h_b	m	18.29	30.00	No source given
	FlexNet Endpoint height h_m	m	1.5	1.5	
	Median propagation model		Free space	W-I LOS (slant distance)	
	PDV eNodeB mechanical downtilt	deg	0	0	PDV's assumption
	Max attenuation due to V antenna pattern SLA_v	dB	20	999	3GPP TR 36.814: multipath fills nulls No consideration of multipath

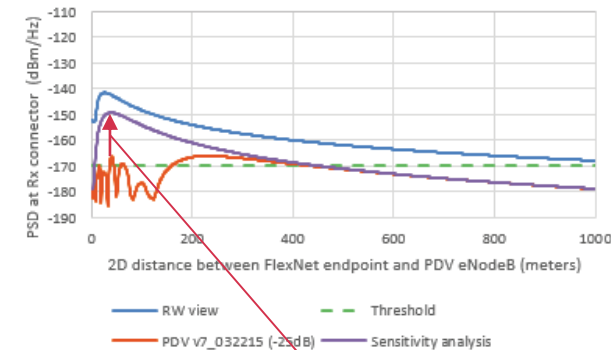
# eNodeB antenna pattern, boresight gain, cable and connector losses

Challenging case - DL

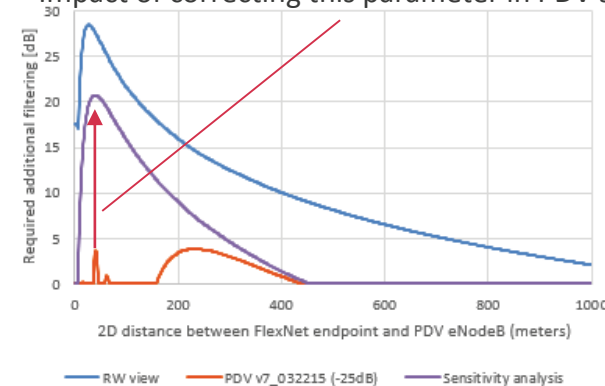
Interpretation A

1

- PDV have assumed that the eNodeB antenna gain is 16dBi, citing ARGUS HPX308R (2deg)
- PDV have assumed that the eNodeB antenna cable and connector losses are 4dB
- The OOB density is expressed in EIRP, hence our view is that the values of antenna gain and cable losses are not relevant
- PDV have assumed that the eNodeB antenna is ARGUS HPX308R (2deg)
- ARGUS HPX308R (2deg) operates in 1525–1710MHz, thus its pattern is not applicable to the desired frequency 938.5MHz
- ARGUS HPX308R (2deg) has a relatively narrow vertical beamwidth. An antenna with a wider vertical beamwidth would exacerbate interference reception close to eNodeB. Amphenol BCD-7001-EDIN-X (Single Band, Omni, V-Pol, 696-960 MHz, 360°, 1.1 dBd, 3.2 dBi, 0°T) has 70 deg vertical beamwidth.
- We note that Amphenol BCD-7001-EDIN-X comes with electrical downtilt options, and that with increasing electrical downtilt, the received interference increases close to eNodeB.
- Our view is that a more appropriate antenna pattern is one that has wide vertical beamwidth such as **70deg and 0 electrical downtilt**
- The impact of varying mechanical/electrical downtilt also has to be taken into account



Impact of correcting this parameter in PDV's calculations



26/06/2015

Vertical beamwidth has been underestimated: Impact of correcting this: +18dB worse interference

# Environmental noise margin

- The basic noise floor seen at a Sensus Endpoint is at thermal noise PSD ( $kT = -174\text{dBm/Hz}$ ) plus the Endpoint's noise figure (4dB based on Sensus data) –  
i.e. **-170 dBm/Hz**
  - The noise floor *may* be raised at individual Endpoints by environmental noise
  - PDV has included a noise margin of 10dB, resulting in a 9.5 dB noise rise to **-160.5 dBm/Hz** This is based on their reading of a collection of studies which made in various environments, but they note that:  
“studies...were difficult to find...deliver values from a limited amount of samples...had to be extrapolated” suggesting a low confidence in their chosen value.
  - As discussed earlier, Sensus have made explicit measurements resulting in an environmental noise margin of **2dB** and individual endpoints may experience less than this
- PDV's suggestion is based on incomplete data and inappropriate environments and is out of line with the real-world environment encountered by FlexNet
  - Impact of correcting this: 7.5 dB worse interference impact (through lowered protection threshold)

26/06/2015

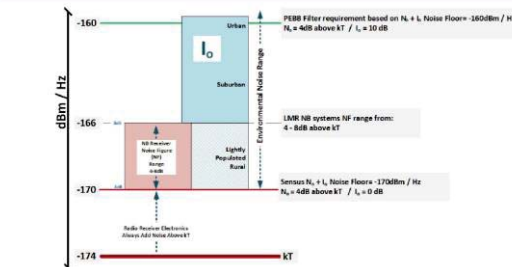
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## Challenging case - DL

### Interpretation A

2

#### PEBB Attenuation Requirements - Noise Floor Reference



Note:  
 $I_o = -160\text{dBm} / \text{Hz}$  based on environmental noise values analyzed & normalized from government sponsored studies in the U.S., England and the EU  
 $N_o = \text{Noise Figure} + kT$  / For this analysis is considered the same as "Thermal Noise"

#### -160dBm Reference Noise Floor – $N_o + I_o$

- IEEE 473 1985 -  
IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz)
- World Metrological Organization  
COMMISSION FOR BASIC SYSTEMS STEERING GROUP ON RADIO FREQUENCY COORDINATION  
Results of Ambient RF Environment and Noise Floor Measurements Taken in the U.S. in 2004 and 2005
- Man Made Noise in Our Living Environment  
International Union of Radio Science  
No. 334, September 2010
- CEPT REPORT 19 - Revision 10/30/08  
Report from CEPT to the European Commission  
in response to the mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS

Note: In their model PDV also cite TIA-TSB-88.2-D

#### Note:

Studies to determine the -160dBm reference noise floor were difficult to find. Publically available studies deliver mean or median values from a limited amount of samples and some cases had to be extrapolated for this analysis to develop a generalized threshold for use in modeling and determining a baseline ceiling reference  $N_o + I_o$  value.

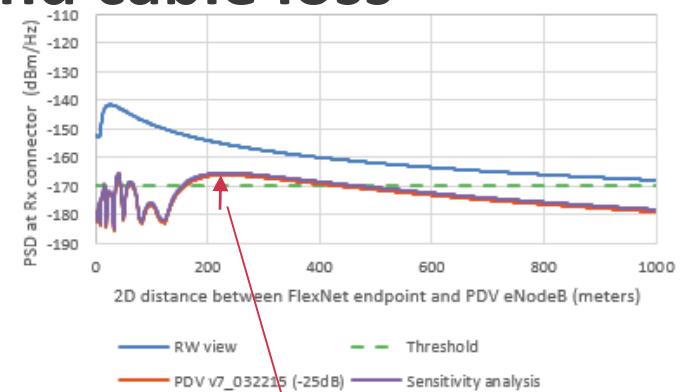
# FlexNet Endpoint antenna gain and cable loss

Interpretation A

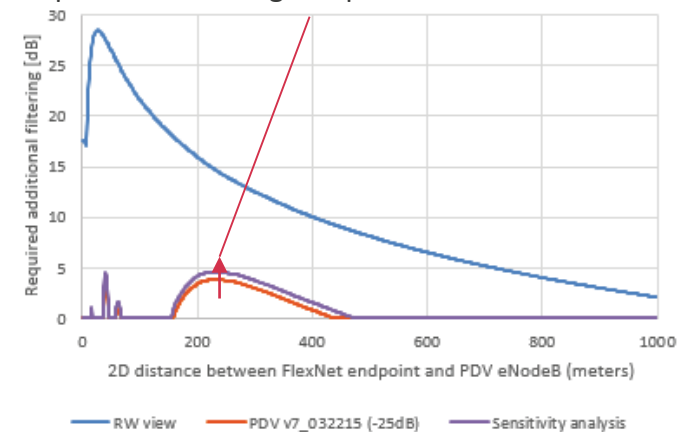
3

- PDV have assumed that the FlexNet Endpoint antenna gain is -1dBd, i.e. **1.15dBi**, without providing any source for this input
- Sensus' data support that the FlexNet Endpoint antenna gain may be at least **0dBi** (or even higher in some cases)
- PDV have assumed that the FlexNet Endpoint antenna cable losses are **1.9dB**, without providing any source for this input
- Sensus' data support that the FlexNet Endpoint antenna cable losses are **0dB**

FlexNet Endpoint antenna gain has been underestimated and cable losses have been overestimated: Impact of correcting this: +0.75dB worse interference



Impact of correcting this parameter in PDV's calculations



# Base station antenna height

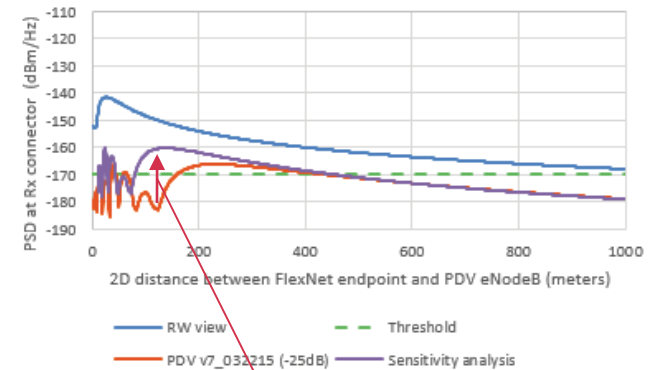
- PDV have assumed a base station antenna height of **98.4'** (30m)
- This is relatively high and LTE eNBs are often operated at lower heights
- In order to protect the Endpoints, a lower antenna height should be considered. Our view is that the height of **60'**, as in the PU2FT calculation (PDV UE to FlexNet base station), should be considered
- The impact of this change is shown opposite

PDV eNB antenna heights may lower than the 98.4' modelled  
Changing the height from 98.4' to 60' increases interference level by about 6 dB

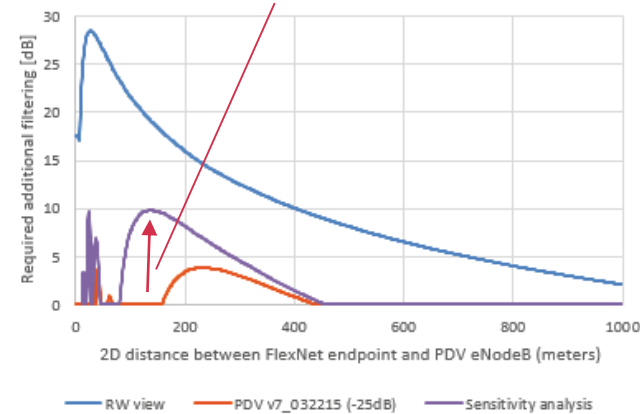
## Challenging case - DL

Interpretation A

4



## Impact of changing height from 98.4' to 60'



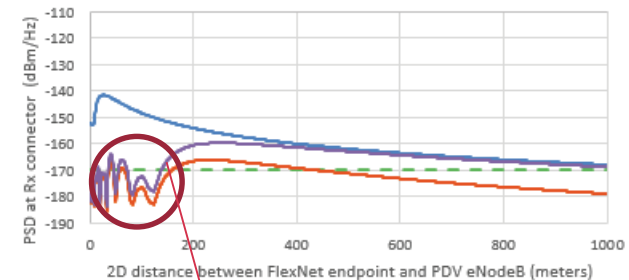
# Propagation model

- As explained earlier we believe that the free space loss model (not W-I LoS) should be used for short range interference calculation
- It has a small (1.4 dB) impact on interference at a range of around 30 m taken on its own
- At longer ranges other propagation models may need to be considered

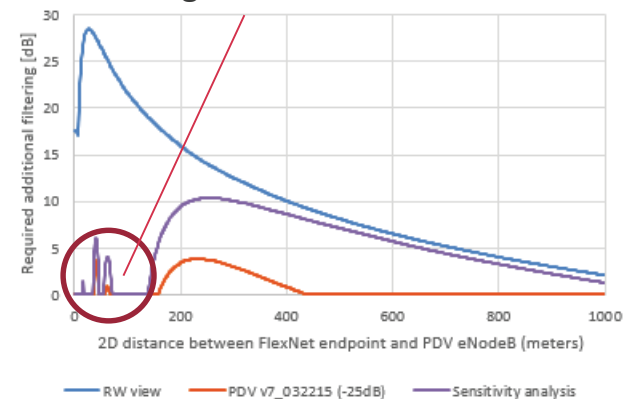
Challenging case - DL

Interpretation A

5



Region of interest



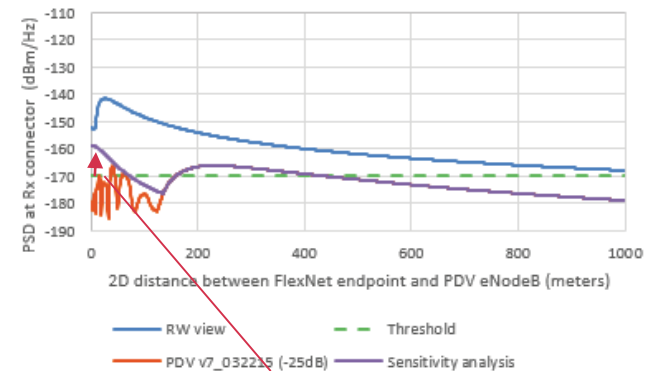
# Maximum attenuation due to antenna pattern

- As discussed earlier, multipath tends to fill base station antenna nulls so these should not be relied on to provide interference protection in particular directions
- PDV has **not considered** this effect
- Capping the attenuation from the antenna at some level, typically around 20 dB (see [2, 3])
- The impact is to significantly increase the level of interference at the shortest ranges, resulting in an extra 8 dB required attenuation

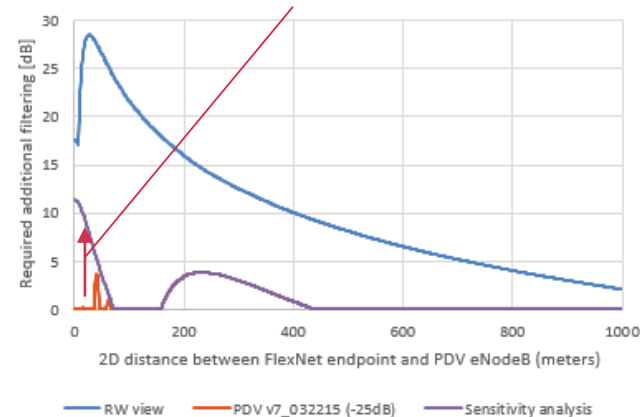
[1] "Antenna pattern measurement technique using wideband channel profiles", Newhall & Rappaport, AMTA 19<sup>th</sup> symp. Boston, Nov. 1997

[2] 3GPP TR 36.942

[3] 3GPP TR 36.814



Impact of accounting for null filling



# Summary of differences (challenging case)

- We believe PDV has understated the impact of interference due to the following inappropriate parameter choices:

#	Parameter	Comment on PDV assumptions	Impact of each correction on interference:
①	eNodeB antenna pattern, boresight gain, cable and connector losses	Vertical beamwidth has been underestimated	+18dB
②	Environmental noise margin	Assumed 9.5 dB noise rise from reference sources, no measurements	+7.5dB
③	FlexNet Endpoint antenna gain and cable loss	FlexNet Endpoint antenna gain has been underestimated and cable losses have been overestimated	+0.75dB
④	Base station antenna height	PDV cause excessive interference when their antennas are at heights lower than 98.4'	+6dB
⑤	Propagation model	Propagation model for a different environment	+1.4dB
⑥	Maximum attenuation due to antenna pattern	No consideration of impact of real environment on nulls	+8dB
	<b>Overall</b>	<b>Effects are not simply additive</b>	<b>~25 dB</b>

## Moderate case parameters

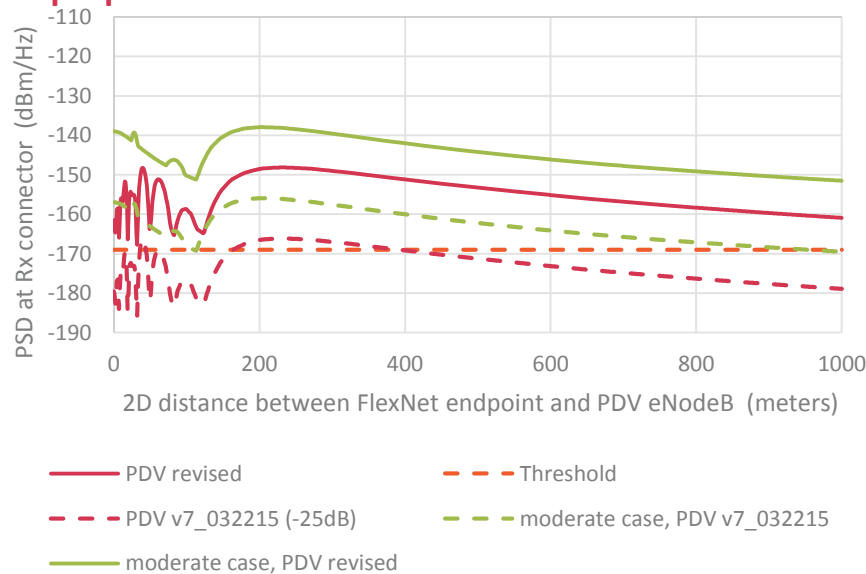
- The following parameters represent a higher likelihood moderate case

#	Parameter		PDV Parameters	RW Challenging case parameters	RW moderate case parameters
1a	eNodeB boresight gain	dBi	16.0	16	16.0
1b	eNodeB antenna pattern		ARGUS HPX308R (2deg)	Amphenol, BCD-87010-6-25 (6 elec. downtilt)	Kathrein 80010736V01 – (realistic LTE eNB antenna for these frequencies)
1c	eNodeB cable and connector losses		4.0	4	4.0
2	Protection level	dBm/Hz	-160.0	-170	-169.0
3	FlexNet endpoint antenna gain & cable loss	dBi	1.15	0	0.0
4	eNodeB antenna height	feet	98.4'	60'	98.4'
5	Propagation model		W-I LOS	Free space	Free Space
6	Maximum antenna attenuation	dB	Unlimited	20	20.0

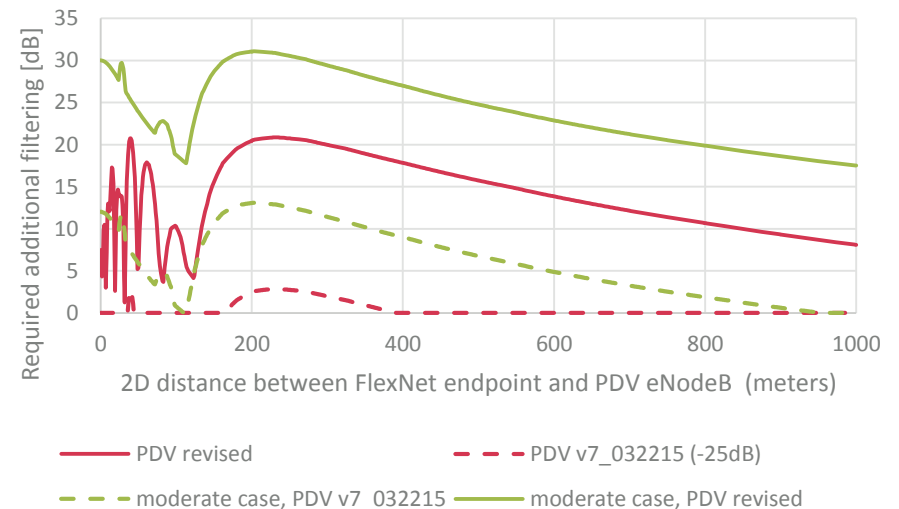
# RW moderate cases

- We have considered the proposed moderate case for the interference calculation.
- The parameters used are shown on the previous slide.

## Comparison of interference levels between PDV proposals for the moderate case



## Required attenuation (additional to threshold) to protect -169dBm/Hz threshold



Our view of parameters indicates that 14 dB of additional attenuation could be required to adequately protect FlexNet Endpoints given the original PDV proposal and **31 dB extra attenuation for the revised PDV proposal**

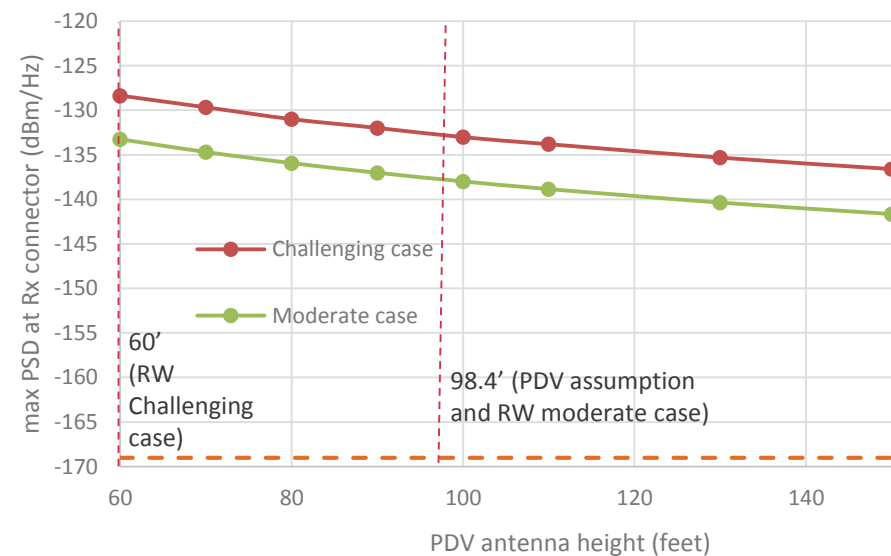
# Effect of PDV eNodeB antenna height

Moderate Case - DL

Challenging case –DL

Interpretation A

- Since we do not know the height at which PDV will deploy its eNodeB base stations, we have varied the eNB height to determine the sensitivity to this parameter
- The graph shows the value of the highest PSD encountered at any distance for a given eNB height
- There is around 5 dB of variation between the PDV assumption and our challenging case
- In all cases the PSD remains above the required protection level





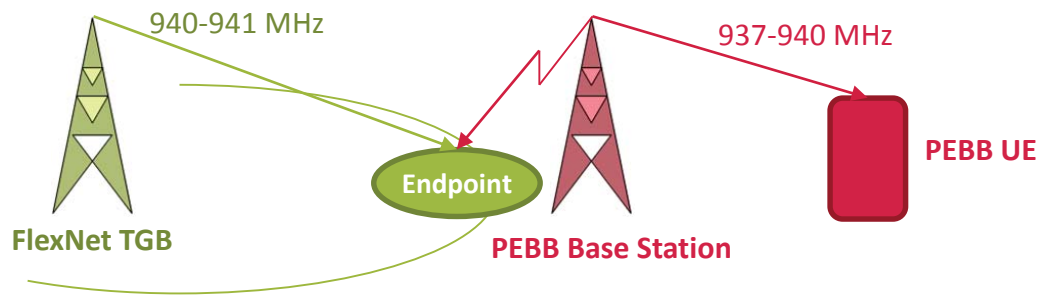
## 9. Interference mode PB2FE (PDV base station to FlexNet endpoint) - Interpretation B

26/06/2015

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# Scenario PB2FE

Interpretation B

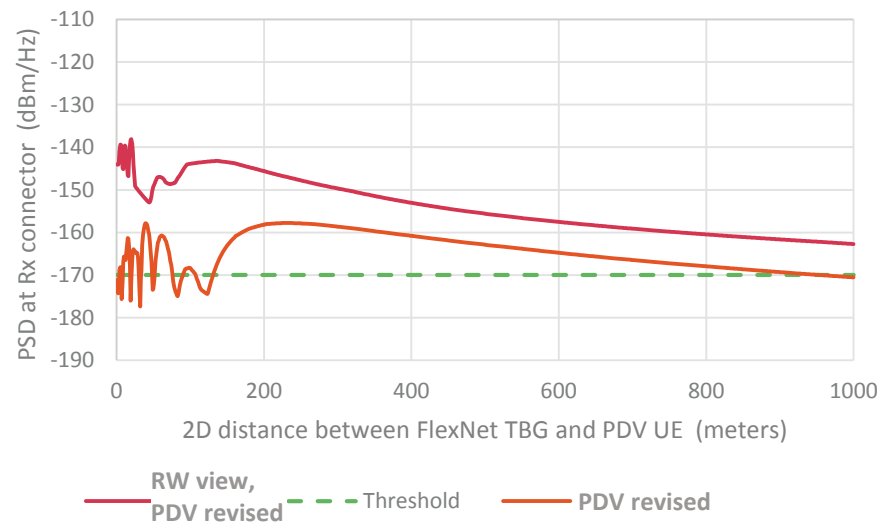


- An endpoint is at the edge of a FlexNet
- A PEBB Base Station is nearby and causes excessive interference to an endpoint Rx

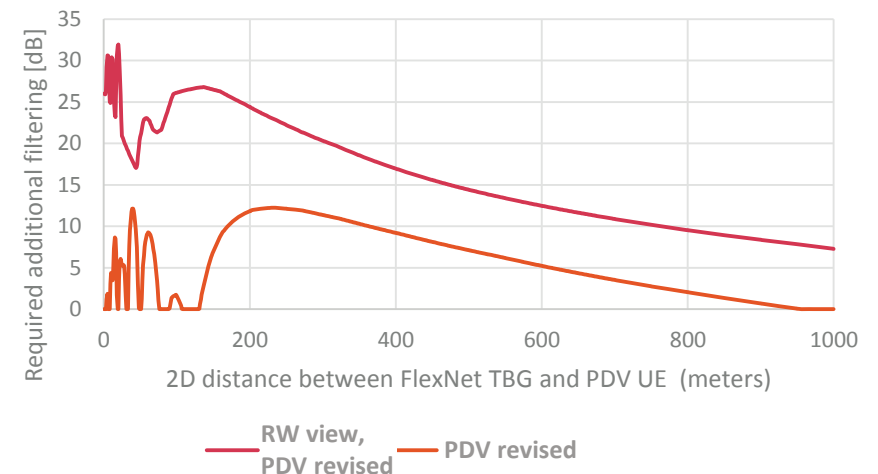
# Real Wireless challenging case outcomes

- The comparison below is based on the PDV proposed emission mask and a protection threshold at -170 dBm/Hz
- The parameters used are compared on the following slide and individually discussed in the remainder of this section

## Comparison of interference levels based on PDV and RW challenging parameter sets



## Required attenuation (additional to the -170 dBm/Hz threshold)



Our view of parameters indicates that 32 dB of additional attenuation could be required to adequately protect FlexNet Endpoints

## Moderate case parameters

- The following parameters represent a higher likelihood moderate case

#	Parameter		PDV Parameters	RW Challenging case parameters	RW moderate case parameters
1a	eNodeB boresight gain	dBi	16.0	16	16.0
1b	eNodeB antenna pattern		ARGUS HPX308R (2deg)	Amphenol, BCD-87010-6-25 (6 elec. downtilt)	Kathrein 80010736V01 – (realistic LTE eNB antenna for these frequencies)
1c	eNodeB cable and connector losses		4.0	4	4.0
2	Protection level	dBm/Hz	-160.0	-170	-169.0
3	FlexNet endpoint antenna gain & cable loss	dBi	1.15	0	0.0
4	eNodeB antenna height	feet	98.4'	60'	98.4'
5	Propagation model		W-I LOS	Free space	Free Space
6	Maximum antenna attenuation	dB	Unlimited	20	20.0

# PDV and RW challenging case parameters compared

Interpretation B

- The calculations on the previous slide are based on the following parameters
- In the subsequent slides we examine each of the 6 issues flagged here

	Symbol	Unit	Value	Value
			<b>RW view</b>	<b>PDV v7_032215 (-25dB)</b>
PDV Tx center frequency f	MHz		938.5	938.0
PDV eNodeB OOB PSD immediately adjacent to channel	dB		55	55
as above in dBm/30kHz ERP	dBm/30kHz ERP		-55.0	-55.0
as above in dBm/100kHz ERP	dBm/100kHz ERP		-25.0	-25.0
as above in dBm/100kHz EIRP	dBm/100kHz EIRP		-19.8	-19.8
as above in dBm/Hz ERP	dBm/Hz ERP		-17.6	-17.6
as above in dBm/Hz EIRP P 1	dBm/Hz EIRP		-69.8	-69.8
			-67.6	-67.6
PDV eNodeB antenna gain	dBi		16.0	16.0
PDV eNodeB cable loss	dB		4.0	4.0
PDV eNodeB antenna pattern			6-25 Amphenol	ARGUS HPX308R (2deg)
OOB EIRP density	dBm/Hz		-67.6	-67.6
Thermal noise PSD	dBm/Hz		-174	-174
FlexNet Endpoint noise figure	dB		4	4
Thermal noise PSD at Rx input	dBm/Hz		-170	-170
Environmental noise margin	dB		2	3.5
Thermal noise PSD at Rx input, incl env. noise	dBm/Hz		-168	-161
FlexNet Endpoint antenna gain	dBi		0	1.15
FlexNet Endpoint cable loss	dB		0	1.9
PDV eNodeB height	feet		60	98.4
h_b	m		18.29	30.00
FlexNet Endpoint height h_m	m		1.5	1.5
Median propagation model			Free space	W-ILOS (slant distance)
Environment			Urban	Urban
PDV eNodeB mechanical downtilt	deg		0	0
Max attenuation due to V antenna pattern SLA_v	dB		20	999

1

2

3

4

5

6

Base station (eNB) transmit system

FlexNet endpoint receive system

Other parameters

# Details about 6 issues

Interpretation B

- Details about the following issues are available in an earlier section of this slidedeck
  - PDV and RW challenging case parameters compared
  - eNodeB antenna pattern, boresight gain, cable and connector losses
  - Environmental noise margin
  - FlexNet Endpoint antenna gain and cable loss
  - Base station antenna height
  - Propagation model
  - Maximum attenuation due to antenna pattern

# Summary of differences (challenging case)

- We believe PDV has understated the impact of interference due to the following inappropriate parameter choices:

#	Parameter	Comment on PDV assumptions	Impact of each correction on interference:
①	eNodeB antenna pattern, boresight gain, cable and connector losses	Vertical beamwidth has been underestimated	+18dB
②	Environmental noise margin	Assumed 9.5 dB noise rise from reference sources, no measurements	+7.5dB
③	FlexNet Endpoint antenna gain and cable loss	FlexNet Endpoint antenna gain has been underestimated and cable losses have been overestimated	+0.75dB
④	Base station antenna height	PDV cause excessive interference when their antennas are at heights lower than 98.4'	+6dB
⑤	Propagation model	Propagation model for a different environment	+1.4dB
⑥	Maximum attenuation due to antenna pattern	No consideration of impact of real environment on nulls	+8dB
	<b>Overall</b>	<b>Effects are not simply additive</b>	<b>~15 dB</b>

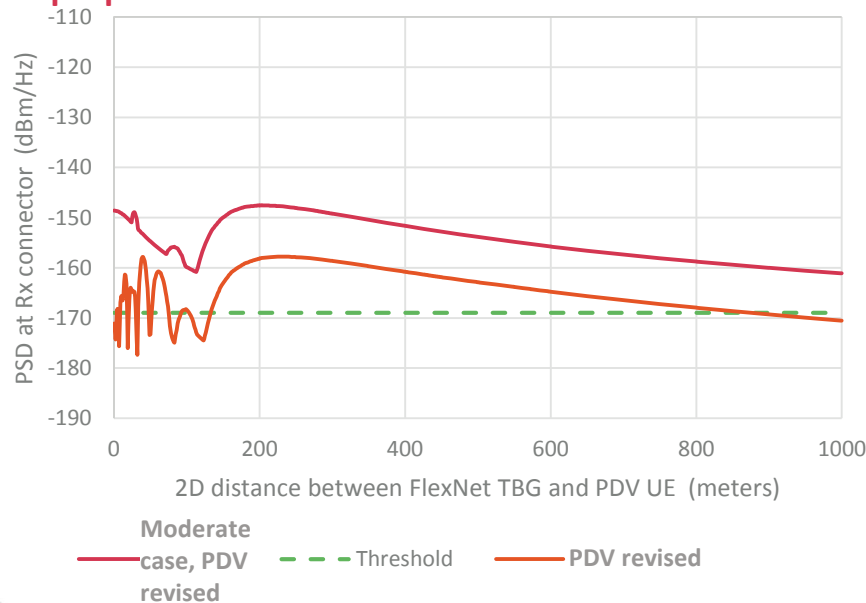
# RW moderate cases

Moderate Case - DL

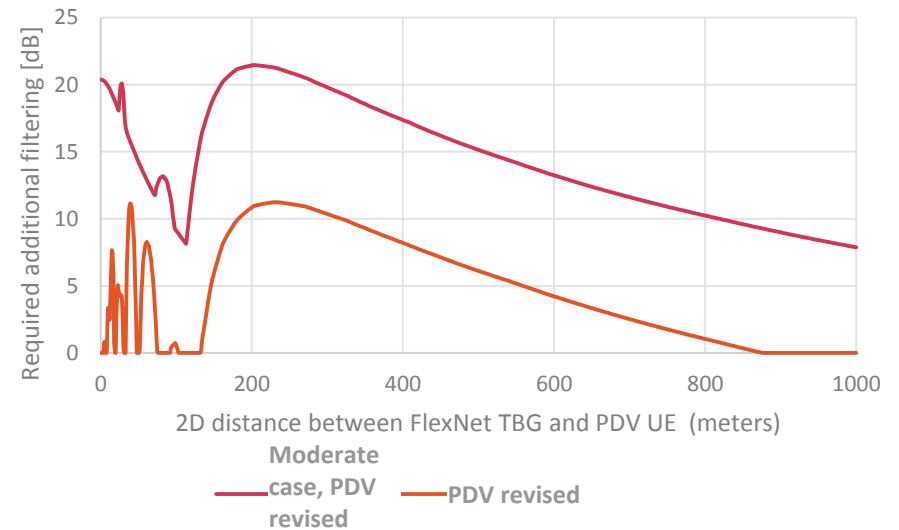
Interpretation B

- We have considered the proposed moderate case for the interference calculation.
- The parameters used are shown on the previous slide.

## Comparison of interference levels between PDV proposals for the moderate case



## Required attenuation (additional to the -169 dBm/Hz threshold threshold)



Our view of parameters indicates that 22 dB of additional attenuation could be required to adequately protect FlexNet Endpoints given the revised PDV proposal



## 10. Summary of findings

26/06/2015

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# Summary of findings

1. Real Wireless has reviewed coexistence calculations and emission specifications proposed by pdvWireless (PDV) to protect adjacent FlexNet systems on behalf of Sensus
2. We have reproduced PDV's calculations using an independent model, **and agree broadly with PDV's calculation methodology**
3. We found that **the interference threshold proposed by PDV is inappropriate**, since it is based on inappropriate noise environment assumptions. Our review of field measurements conducted by Sensus suggests a threshold around **-170dBm/Hz** rather than the -160 dBm/Hz proposed by PDV
4. We have conducted a detailed review of the calculation parameters proposed by PDV and found that in many cases **the parameters are inappropriate**, resulting in a far greater level of interference than PDV has suggested
5. The table below summarises our findings regarding the extra attenuation needed for each: interference mode (uplink, downlink) case (challenging, moderate) and the interpretation of the proposed limits (A or B): Even in moderate cases **tens of dB extra attenuation is needed**
6. Additionally the **test conditions for specifying emission limits need to be properly specified** to account for the measured characteristics of real LTE devices: this could create a 7dB increase in emissions compared with the test conditions specified by PDV

Interference mode				Challenging Case		Moderate Case	
		Rule proposal	Interpretation	A	B	A	B
PDV UE aggressor to Sensus TGB victim (PU2FT)	UL	03-May	PSD dBm/Hz	-116	-114	-141	-139
			Extra attenuation needed (dB)	54	56	27	29
PDV eNodeB aggressor to Sensus endpoint victim (PB2FE)	DL	25-Mar	PSD dBm/Hz	-146		-155	
			Extra attenuation needed (dB)	24		14	
		03-May	PSD dBm/Hz	-128	-138	-138	-147
			Extra attenuation needed (dB)	42	32	31	22



## **Annex 1: LTE user equipment out of band emission measurements**

26/06/2015

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# Introduction

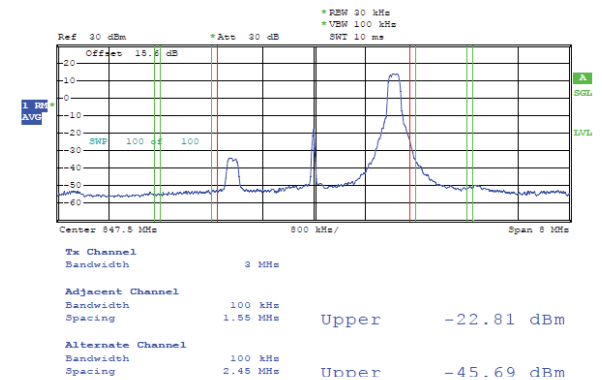
- We have reviewed FCC reports for several LTE devices [1] to determine the practical outcome and test conditions for UE out of band emission measurements
- Results are shown in the next few slides, with a summary of the outcomes at the end

[1] FCC reports from [https://apps.fcc.gov/edocs\\_public/](https://apps.fcc.gov/edocs_public/)

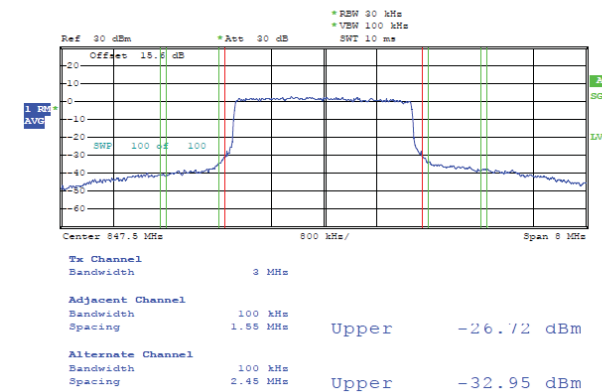
# ZTE Z930L 4G Phone FCCID:SRQ-Z930L

- The worse case plot is -22.81 dBm/30 kHz which would relate to -17 dBm/100 kHz.

Higher Band Edge Plot for QPSK-RB Size 1, RB Offset 14

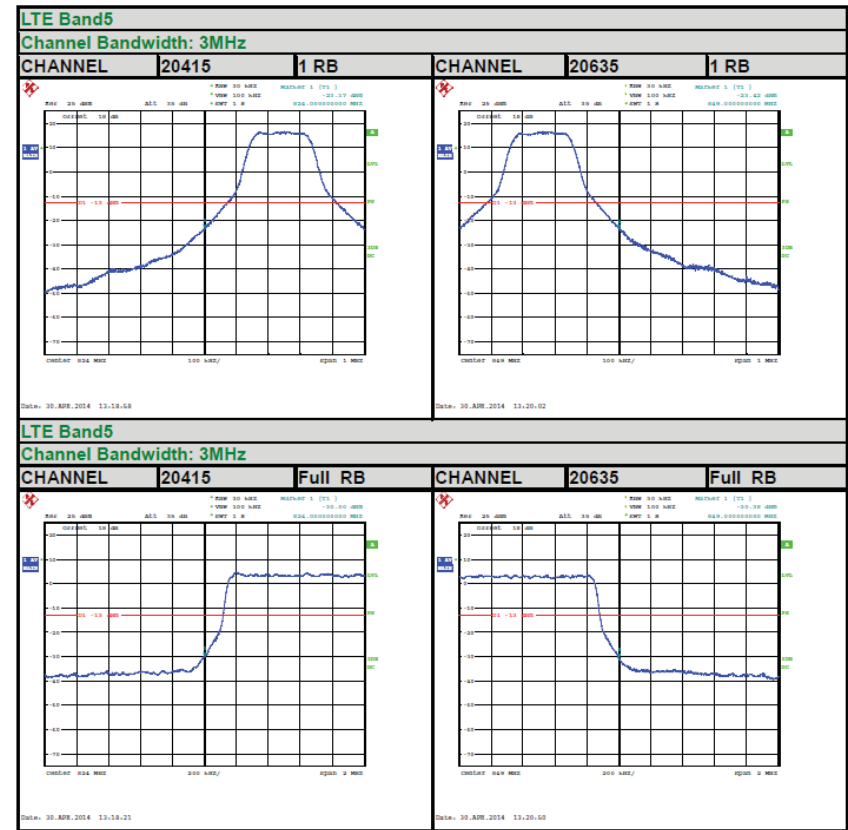


Higher Band Edge Plot for QPSK-RB Size 15, RB Offset 0



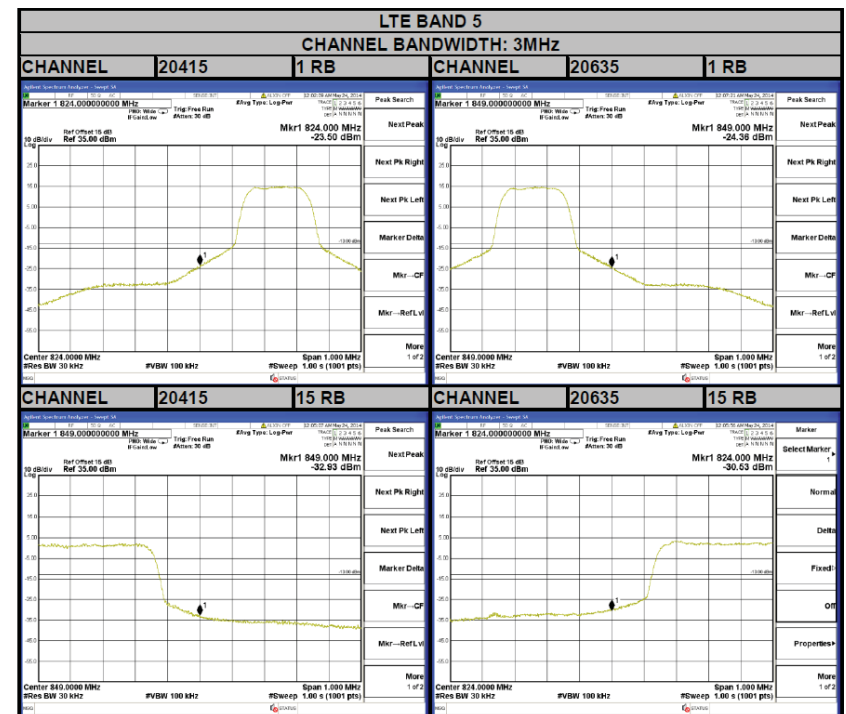
# Sonim 4G Phone FCCID:WYPL11V012AA

- Note, the emissions are measured in a 30 kHz bandwidth. The worse case plot is -23.17 dBm/30 kHz which would relate to -18 dBm/100 kHz.



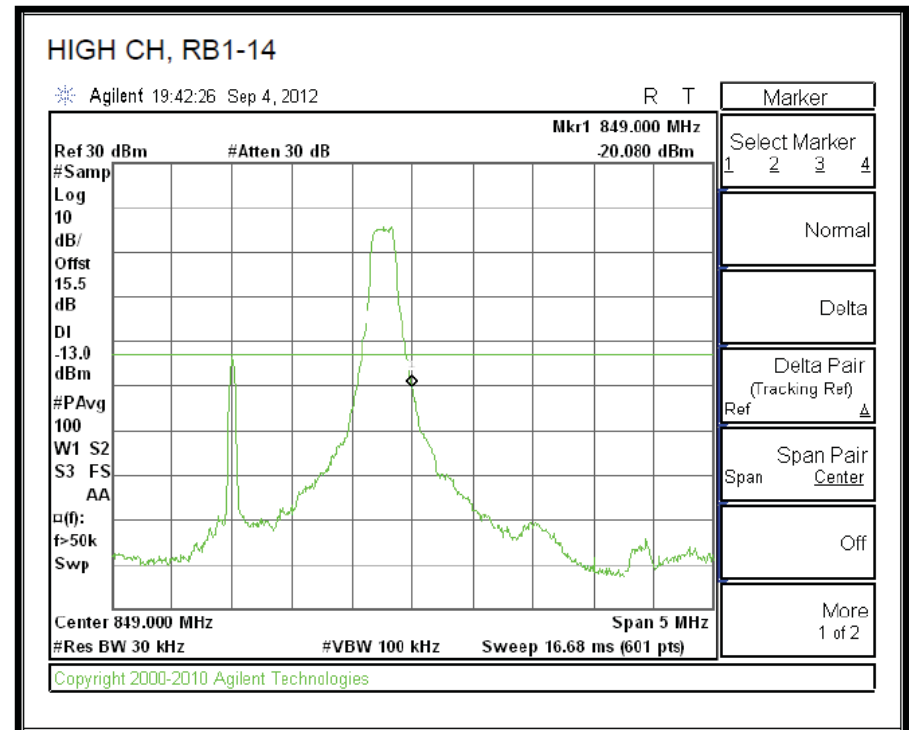
# Asus 4G Phone FCCID:MSQT00S

- Note, the emissions are measured in a 30 kHz bandwidth. The worst case plot is -23.50 dBm/30 kHz which would relate to -18.3 dBm/100 kHz.



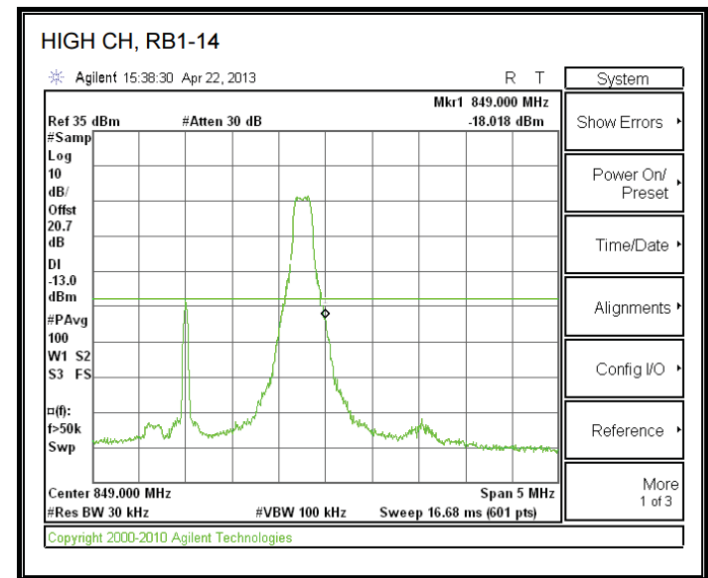
# Apple iPad FCCID:BCGA1460

- QPSK Band 5 3MHz Bandwidth LTE
- Measurement is in 30 kHz bandwidth and shows -20.08 dBm. In 100 kHz bandwidth, this would relate to a reading of -15.5 dBm/100 kHz.



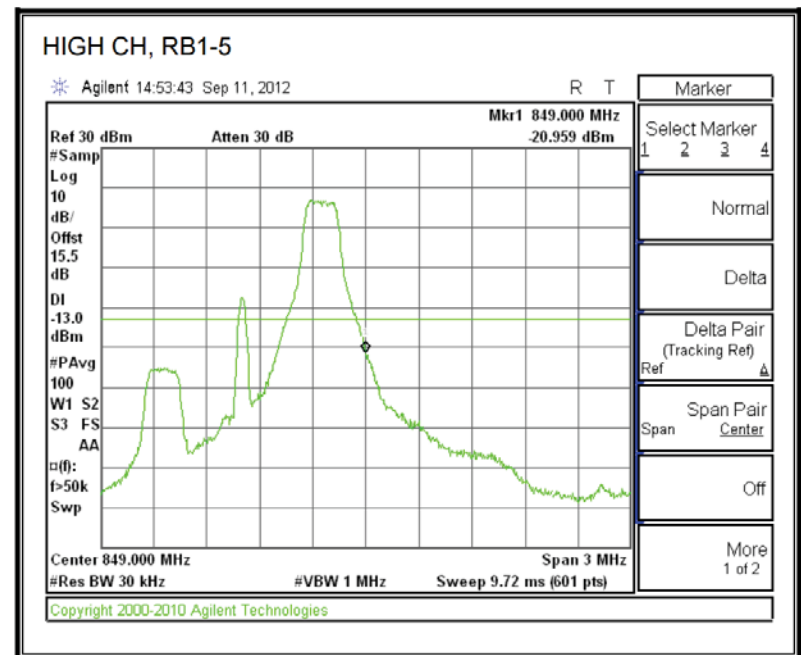
# Apple iPad FCCID:BCG-E2642A (AKA iPhone5)

- QAM Band 5 3MHz Bandwidth LTE
- Measurement is in 30 kHz bandwidth and shows -18.02 dBm.
- In 100 kHz bandwidth, this would relate to a reading of -12.8 dBm/100KHz.



# Apple iPad FCCID:BCGA1455

- QPSK Band 5 3MHz Bandwidth LTE
- Measurement is in 30 kHz bandwidth and shows -20.96 dBm. In 100 kHz bandwidth, this would relate to a reading of -15.6 dBm/100 kHz.



## Summary of results

Device	Emissions @ 150kHz from band edge (dBm/ 30 kHz)	
	All resource blocks active	1 resource block active
ZTE Z930L 4G Phone FCCID:SRQ-Z930L	-26.7	-22.8
Sonim 4G Phone FCCID:WYPL11V012AA	-30.0	-23.2
Asus 4G Phone FCCID:MSQT00S	-30.5	-23.5
Apple iPad FCCCID:BCGA1460	Not available	-20.1
Apple iPad FCCCID:BCG-E2642A (AKA iPhone5)	Not available	-18.0
Apple iPad FCCCID:BCGA1455	Not available	-21.0

## Annex 1 Summary

- PDV has proposed an emission limit for UEs of  $(55+10 \log(P))$  dB below carrier measured in 30kHz
- For a given UE EIRP  $P$  this equates to  $30-55+10\log(100/30)$  dBm/30 kHz = -25dBm/30 kHz, i.e. 12 dB tighter than the 3GPP specification of -13dBm/30 kHz (assuming 0dBi/0dB UE antenna gain/feeder loss)
- FCC reports for several manufacturers representing widely deployed LTE phones have been reviewed
- Many of the phones tested produce  $> -20$  dBm/100kHz
- The worst case of those reviewed is the iPhone 5, which at -12.8 dBm/100 kHz does exceed PDV's proposed limit by over 7dB
- We find that out of band emission levels depend critically on the test conditions, with emissions being largest when the UE is transmitting in a single resource block rather than over the entire 3 MHz bandwidth, with up to 7dB difference between the two cases

## Annex 2: Abbreviations

Abbreviation	Meaning
ACLR	Adjacent Channel Leakage Ratio
ACIR	Adjacent Channel Interference Ratio
ACS	Adjacent Channel Selectivity
CDF	Cumulative Distribution Function
CPE	Customer Premises Equipment
eNB	enhanced NodeB
EIRP	Effective Isotropic Radiated Power
ERP	Effective Radiated Power
FCC	Federal Communications Commission
kHz	Kilohertz
LoS	Line of Sight
LTE	Long Term Evolution
MHz	Megahertz
OOBE	Out of Band Emission
PDV	Pacific DataVision
PEBB	Private Enterprise Broadband – PDV term for its use of the spectrum in scope
PSD	Power Spectral Density
Rx	Receiver
TGB	Tower Gateway Basestation
Tx	Transmitter
UE	User Equipment

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